United States
Environmental Protection
Agency

Office of Pesticide
and Toxic Substances
Washington, DC 20460

EPA 560 5-83-002
March 1983

Toxic Substances

EPA

Guidance for Controlling Friable Asbestos-Containing Materials in Buildings

EPA Report Number 560/5-83-002
March 1983

GUIDANCE FOR CONTROLLING FRIABLE ASBESTOS-CONTAINING MATERIALS IN BUILDINGS

Field Studies Branch
Design and Development Branch
Exposure Evaluation Division
Office of Toxic Substances
Office of Pesticides and Toxic Substances
U.S. Environmental Protection Agency
Washington, D.C. 20460

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES
(Continued)

Acknowledgments

The assistance of the many individuals who contributed their time and efforts to the preparation of this document are gratefully acknowledged. Dale Keyes, an independent consultant, and Bertram Price of Battelle Memorial Institute served as primary authors of the document. They prepared the initial draft and revised it to reflect a series of detailed reviews. Joseph Breen and Cindy Stroup (Office of Toxic Substances, Exposure Evaluation Division) served as Task Managers and directed the report preparation process. The material presented here reflects many hours of discussion among local school officials, health and environmental scientists, architects, engineers, and staff at EPA Headquarters and in the Regional Offices. The document was developed and refined through a series of meetings with three groups—a working group consisting of EPA staff from the Office of Toxic Substances (OTS); a larger review group consisting of the OTS working group, EPA staff from the Office of Research and Development (ORD), and Regional Asbestos Coordinators from EPA Regional Offices; and a peer review group consisting of school officials and technical specialists who are not EPA employees.

The OTS working group provided thorough and timely criticism, suggestions, and assistance in formulating the presentation of the more complex issues. The working group members were:

Joseph Breen, Exposure Evaluation Division

James Bulman, Chemical Control Division

Dave Mayer, Chemical Control Division

Richard McAllister, Chemical Control Division

Cindy Stroup, Exposure Evaluation Division

The larger EPA review group met early in the process to outline the document and to decide which areas needed to be emphasized. In addition to persons listed above, the group consisted of:

Michael Beard, Office of Research and Development/Environmental Monitoring Systems Laboratory

Wolfgang Brandner, EPA Region VII

Dwight Brown, EPA Region IV

William Cain, Office of Research and Development/Industrial Environmental Research Laboratory

Carol Grove, Office of Research and Development/Center for Environmental Research Information

Pamela Harris, Office of Pesticides and Toxic Substances/Enforcement Division

Tony Restaino, EPA Region V

Gilbert Wood, Office of Air Quality Planning and Standards/Emission Standards Engineering Division

The members of this group were also active participants in the three-day peer review meeting. We thank all of them for their contributions.The Regional Asbestos Coordinators deserve special recognition. Their insights and suggestions based on experience gained in the field were invaluable. Wolfgang Brandner was especially helpful in providing details about specific evaluation and assessment procedures developed in Region VII.

The peer review group members were:

Gene Brantly, Research Triangle Institute, Research Triangle Park, North Carolina

Ron Goodwin, The School District of Greenville County, South Carolina

Don W. Handley, The School District of Philadelphia, Pennsylvania

Ernest Lory, Port Hueneme, California

William Nicholson, Mt. Sinai School of Medicine, City University of New York, New York, New York

Patrick Sebastien, Institute of Occupational Health & Safety, McGill University, Montreal, Quebec

George Smart, George Smart Architects, Inc., Raleigh, North Carolina

Their active participation in the peer review meeting, the speed with which they reviewed all drafts, and their commitment and dedication to the task of disseminating information and guidance for the control of exposure to airborne asbestos are greatly appreciated.

Other contributors participated at various stages in the report preparation. In particular, we wish to thank Project Officers Joseph Carra and Frederick Kutz (Office of Toxic Substances, Exposure Evaluation Division), Suzanne Rudzinski (Office of Toxic Substances, Chemical Control Division), John Lerohl (Office of Toxic Substances, Chemical Control Division), and Donald Lentzen (Research Triangle Institute).

Special appreciation is extended to Ms. Terri Stiteler of Battelle who assisted in analyzing and incorporating comments of the review groups, organizing review group sessions, and directing the preparation and distribution of drafts and the final document.

The Dynamac Corporation is also acknowledged for its role in organizing the peer review meeting, as well as other support staff at EPA and at Battelle for contributing to the successful completion of the project.

Executive Summary

The Environmental Protection Agency (EPA) has been concerned about the disease-causing potential of exposure to airborne asbestos in nonindustrial settings since the early 1970s. In the late 1970s, attention was focused on schools and other buildings where asbestos is present in a variety of construction materials. EPA initiated a Technical Assistance Program (TAP) to help school districts identify and correct potential asbestos hazards. As part of this program, in 1979 EPA prepared and distributed "Asbestos-Containing Materials in School Buildings: A Guidance Document," Parts 1 and 2, which describes how to establish an asbestos identification and control program. It provides both background information and direction for school officials on exposure assessment and the control of asbestos-containing materials.

During the four years since publication of the guidance document, EPA has gathered additional information and has gained valuable experience in assessing the need for corrective action and in controlling the release of fibers from asbestos-containing materials. The purpose of the present document is to supplement previous EPA guidance by emphasizing recent experience and new information on asbestos control. The guidance is important not only for school officials, but also for building owners in general who may have to consider implementing an asbestos control program.

The document serves six specific functions:

(1) To provide a current summary of data on exposure to airborne asbestos;

(2) To identify organizational and procedural issues in establishing an asbestos control program;

(3) To review technical issues confronted when assessing the potential for exposure to airborne asbestos in particular indoor settings;

(4) To summarize and update information on the applicability, effectiveness, and relative costs of alternative remedial actions;

(5) To suggest a structured process for selecting a particular course of action, given information on exposure levels, assessment methods, and abatement techniques; and

(6) To introduce and discuss criteria for determining successful asbestos control.

Substantial scientific uncertainty accompanies many of the technical considerations in the assessment of exposure to airborne asbestos, and the success of any specific abatement action often depends on the circumstances in which it is undertaken. Nevertheless, decisions regarding the need for and types of control must be made. For those readers who previously have been involved in the Asbestos-in-Schools program, the guidance offered will serve as a review and update of familiar issues. For those confronted with the problem of controlling asbestos for the first time, the document will identify the critical issues, introduce information on asbestos exposure and control, and direct the reader toward the structured development of an asbestos control program.

The focus of this report is asbestos-containing material in friable form. Friable materials have a greater potential for fiber release and thus pose a greater hazard than other forms of asbestos-containing materials. Nonfriable materials which contain asbestos also are addressed, but only regarding the need for documentation and periodic inspection.

The report is organized in four chapters. Background information on health risks and asbestos exposure levels is presented in Chapter 1. Chapter 2 emphasizes the organizational and procedural aspects of developing and managing an asbestos control program. Chapter 3 discusses the key technical issues associated with assessing the need for corrective action and selecting an asbestos control measure. Chapter 4 focuses on criteria for determining that an asbestos abatement project has been successfully completed. The key issues and recommendations are summarized at the beginning of each chapter and are provided below.

Health Effects and Exposure

- Exposure to airborne asbestos, regardless of the level, involves some health risk.
- Children and young adults who are exposed to asbestos have a greater chance than older people of developing certain asbestos-related diseases, due to a longer remaining lifespan during which disease may develop. Also, smokers exposed to asbestos are at greater risk than nonsmokers experiencing a similar level of exposure.
- Prevalent levels of airborne asbestos inside buildings where asbestos-containing materials are present may exceed outdoor levels by a factor of 100. However, these indoor levels are lower by a factor of at least 1,000 than historic asbestos workplace levels where the occurrence of asbestos-related disease is well documented. When asbestos-containing materials are damaged, peak levels inside buildings may approach historic workplace levels.
- Current regulations restrict the use of asbestos in new buildings, specify work practices during the removal of asbestos-containing materials from existing buildings, and require the identification of asbestos in schools. No exposure standards have been established for nonindustrial settings, and no regulations mandate which corrective actions need to be taken in buildings where asbestos-containing materials are found.
- The potential for exposure to airborne asbestos in buildings and the associated risk of asbestos-related disease cannot be ignored. The decision whether or not to take action and the selection among alternative courses of action are the responsibility of the individual building owner.

Developing a Control Program

- A building owner should delegate the responsibility for directing and managing the control program activities to one individual. This person is called the asbestos program manager.
- A program plan is needed to address:
  - detection of asbestos-containing materials;
  - assessment of the exposure potential;
  - evaluation of control options;
  - management of a control program; and
  - recordkeeping.
- Managing a control program is a complex undertaking requiring:
  - identification and selection of technical experts;
  - training of control program staff;
  - selection of contractors;
  - supervision of workers; and
  - recordkeeping.

Implementing a Control Program

- Buildings should be inspected for friable materials, and building records should be checked for specifications of both friable and nonfriable asbestos-containing materials.
- Friable materials should be sampled and analyzed for the presence of asbestos. Procedures for sampling and analysis are described in previous EPA guidance.
- If asbestos-containing materials are present, the need for corrective action should be assessed. Assessment factors identified in previous EPA guidance are useful qualitative tools. Numerical scoring and index systems have not proven reliable. Air monitoring as a tool for assessing the need for corrective action is not recommended at this time. However, air monitoring may play a role in determining the successful completion of abatement projects, as noted below.
- Four control alternatives should be considered: removal, enclosure, encapsulation, and a special maintenance and operations program.
- Specific cleaning procedures should be instituted to reduce levels of airborne asbestos while waiting for an abatement action to begin.
- A continuing program of special maintenance and periodic reassessment is needed even after an abatement has been completed, unless the asbestos-containing material has been removed.

Determining Abatement Completion

- Visual inspection should be conducted to ensure that all work is complete and that the worksite is free of dust and debris.
- Air monitoring of total airborne fibers by phase contrast microscopy should supplement visual inspection to determine project completion. The use of air monitoring in this situation does not establish that the building is free of airborne asbestos fibers after abatement. Rather, it is used to determine that elevated fiber levels resulting from the abatement work have been reduced.

CHAPTER 1 — EXPOSURE TO ASBESTOS INSIDE BUILDINGS

The Environmental Protection Agency (EPA) has been concerned with the disease-causing potential of nonindustrial exposure to asbestos since the early 1970s. The concern derives from epidemiologic evidence linking airborne asbestos exposures by asbestos workers to various types of cancer and nonmalignant respiratory diseases, and from recognition that large quantities of asbestos have been found in building materials, insulation, and other products used in schools and other buildings. This chapter (1) summarizes information on the relationship between health effects and exposure to airborne asbestos; (2) describes federal regulations affecting asbestos emissions, the use of asbestos materials, and worker exposure levels; and (3) compares levels of airborne asbestos in buildings with those in asbestos workplace settings and outdoors. The purpose of the chapter is to place in perspective asbestos exposure levels and health risks likely to be experienced by occupants of buildings with asbestos-containing materials. The basic exposure-risk issues are summarized below.

Safe Level of Exposure: EPA and the scientific community believe that any level of exposure to asbestos involves some health risk, although the exact degree of risk cannot be reliably estimated. The risk of cancer is of greater concern at low exposure levels than the risk of asbestosis.

Special Concerns: Children and young adults who are exposed to asbestos have a greater chance than older people of developing certain asbestos-related diseases due to a longer remaining lifespan during which disease may develop. Also, smokers exposed to asbestos are at greater risk than nonsmokers with a similar *level of exposure.*

Federal Regulations Affecting Asbestos in Buildings: Current regulations restrict the use of asbestos in new buildings, specify work practices during removal of asbestos-containing materials from existing buildings, and require the identification of asbestos in schools. No exposure standards have been set for nonindustrial settings, and no regulations mandate corrective actions in buildings where asbestos-containing materials are found.

Relative Exposure Levels in Buildings: Prevalent levels of airborne asbestos inside buildings where asbestos-containing materials are present may exceed outdoor levels by a factor of 100. However, these indoor levels are lower by a factor of at least 1,000 than historic asbestos workplace levels where the occurrence of asbestos-related disease is well documented. When asbestos-containing materials are damaged, peak levels inside buildings may approach historic workplace levels.

Need for Action: The level of airborne asbestos in buildings with asbestos-containing materials represents a potential for exposure and risk of asbestos-related disease that cannot be ignored. The decision whether or not to take action and the selection among different courses of action are responsibilities of individual building owners.

1.1 Health Effects Related to Asbestos Exposure

Exposure to high levels of airborne asbestos is associated with a debilitating lung disease called asbestosis; a rare cancer of the chest and abdominal lining called mesothelioma; and cancers of the lung, esophagus, stomach, colon, and other organs. The relationship between exposure level and health risk is complex. The best available data on asbestos worker exposure indicate that the risks of asbestosis, lung cancer, and mesothelioma decrease in direct proportion to a decrease in total asbestos exposure (the average airborne asbestos concentration multiplied by the duration of exposure). At exposure levels below those allowed for asbestos workers, the risk of asbestosis is negligible. Some scarring of lung tissue may appear on X-rays after many years of low exposure, but no impairment of respiratory function is likely to occur. However, the incidence of lung cancer and mesothelioma exceeds baseline rates even at very low exposure levels. This conclusion is supported by the increased incidence of lung cancer for workers experiencing the equivalent of five years' exposure to airborne asbestos at the current federal workplace standard (USEPA 1982). In addition, mesothelioma has been found in persons whose only known exposure to asbestos was from living in a household with asbestos workers or in the neighborhood of asbestos mines, mills, or processing facilities (USEPA 1982).

Asbestos-related lung cancer usually appears after age 45, and its occurrence is heavily influenced by cigarette smoking. For example, in one study of asbestos workers, smokers experienced a fiftyfold increased incidence of lung cancer compared with similarly-aged workers who neither smoked nor were exposed to asbestos. Among the nonsmoking asbestos workers, only a fivefold increase in incidence was found (USEPA 1982).

The age at which asbestos exposure occurs is relatively unimportant for determining the lifetime risk of lung cancer for people less than 45 years old. Asbestos inhaled at age 15 has virtually the same effect in terms of lifetime risk as asbestos inhaled at age 40. In contrast with lung cancer, the age at which asbestos exposure occurs is very important in determining the lifetime risk of developing mesothelioma. This fact creates a special concern for asbestos exposure in children. Studies of workplace exposure indicate that, for persons exposed for several years, the probability of developing mesothelioma remains constant for an initial period and then increases continuously with time from onset of exposure. Since children have a greater remaining lifespan than adults, their lifetime risk should be greater. For example, asbestos workplace studies suggest that a child exposed from age 5 to 10 has at least 10 times the chance of developing mesothelioma as does an adult exposed to the same amount of asbestos between ages 35 and 40.*

1.2 EPA and OSHA Regulations Related to Asbestos

Both EPA and the Occupational Safety and Health Administration (OSHA) have published regulations to reduce exposure to asbestos. The EPA rules have focused on two aspects of asbestos in buildings: (1) the application of asbestos-containing materials in new or remodeled buildings, and (2) the identification of friable† asbestos in schools. In addition to these rules, EPA has regulated the emission of asbestos fibers from the handling of asbestos in asbestos industries and the disposal of asbestos-containing waste. The OSHA regulations address worker protection in asbestos workplaces.

EPA has issued two sets of regulations. The first set was promulgated under the National Emission Standards for Hazardous Air Pollutants (NESHAPS) as authorized in the Clean Air Act. This set of regulations includes a 1973 ban on the use of spray-applied asbestos-containing materials in buildings for insulating or fireproofing purposes, except for equipment and machinery, as well as the specification of "no visible emissions" from permitted spraying, as published in the FEDERAL REGISTER (38 FR 8826).†† Methods of removing friable asbestos from buildings during demolition also were regulated at this time. The ban was amended in 1975 to include molded and wet-applied insulation, as published in the FEDERAL REGISTER (40 FR 48292). In addition, rules governing asbestos removal were broadened to include building renovation, and procedures for disposal of removed materials were defined. Finally, the ban on spraying asbestos-containing materials was broadened in 1978 to include

* Personal communication with William Nicholson, Mt. Sinai School of Medicine, 1982.

† The difference between friable and nonfriable materials is discussed in the introduction to Chapter 2.

†† Materials with less than 1 percent of asbestos by weight were excluded from the ban.

decorative applications, but also was clarified to exclude all applications covered with a particular type of nonfriable material, as published in the FEDERAL REGISTER (43 FR 26372). In addition to these regulations, emission standards have been promulgated under NESHAPS for asbestos mills, asbestos manufacturing facilities, and asbestos fabrication plants. (See 40 CFR, Part 61, Sections A and B for a compilation of all asbestos regulations issued under NESHAPS.)

The second set of EPA regulations is contained in the "Friable Asbestos-Containing Materials in Schools, Identification and Notification Rule," as published in the FEDERAL REGISTER (47 FR 23360). Known as the Asbestos-in-Schools rule, it requires all private and public primary and secondary schools to inspect, sample, and analyze friable materials to determine if asbestos is present. If friable asbestos is present, all school employees must be informed of the location of these materials and each custodial or maintenance employee must be provided a copy of the EPA publication, "A Guide for Reducing Asbestos Exposure," as published in the FEDERAL REGISTER (47 FR 23360). In addition, the school's parent-teacher group (or parents, if there is no organized group) must be notified of the presence of friable asbestos.

The OSHA regulations were first issued in 1972 and modified in 1976. (See 29 CFR, Part 1910 for the complete text.) They specify airborne exposure standards for asbestos workers, engineering and administrative controls, workplace practices, and medical surveillance and worker protection requirements. In 1982, OSHA announced its intention to make the exposure standards more stringent.* (See the "Calendar of Federal Regulations," published in the FEDERAL REGISTER [47 FR 1807].) The OSHA regulations apply to all workplace activities involving asbestos, including removal of asbestos-containing materials from buildings.

Although the NESHAPS and OSHA regulations include standards to reduce exposure to airborne asbestos, the standards were designed primarily to protect the health of people living near asbestos plants, working in the asbestos industry, or removing asbestos from buildings. Exposure to asbestos by persons occupying buildings with asbestos-containing materials is not addressed directly by the standards. Specifically, EPA's NESHAPS for asbestos are directed only at emissions into the outside air (no "visible emissions" resulting from asbestos-handling operations) and do not apply to indoor levels.

OSHA provides specific worker exposure standards, but the application of these standards to nonindustrial settings is inappropriate for two reasons. First, the current standards were set to protect workers against only asbestosis, not cancer. Second, the measurement technique for airborne fibers required to determine OSHA compliance cannot distinguish between asbestos and nonasbestos fibers. The measurement problem is not a major shortcoming in industrial settings where most airborne fibers are expected to be asbestos. However, airborne asbestos may represent only a small fraction of all fibers in the air in buildings, and the OSHA measurement technique may produce misleading conclusions. (Other limitations of the OSHA technique further confound the measurement of airborne asbestos in buildings. See Chapter 3, Section 3.2.3, for a more detailed discussion of measuring airborne asbestos.)

EPA's concern about potential indoor exposure is reflected in the Asbestos-in-Schools rule. Its intent is to reduce exposure to asbestos by locating asbestos-containing materials and alerting school employees and parents of school children to the presence of asbestos. However, standards for allowable airborne asbestos concentrations or exposure levels are not specified.

*As of July 1, 1976, the OSHA standards were set at 2 fibers per cubic centimeter averaged over 8 hours and a ceiling level not to exceed 10 fibers per cubic centimeter "at any time". OSHA is now evaluating the effect of lowering the 8-hour standard to either 0.5 or 0.1 fibers per cubic centimeter in order to protect workers against cancer, as published in the FEDERAL REGISTER (47 FR 1807).

1.3 Airborne Asbestos Levels in Buildings and the Potential Health Risk

Although quantitative estimates of the health risk from exposure to asbestos in buildings are not reliable, a general sense of the risk can be obtained by comparing levels of airborne asbestos measured in buildings with those observed outdoors and in asbestos workplaces. Historical workplace data will be used, since much of the evidence linking asbestos exposure with specific diseases is based on industrial exposure before 1970.

Most investigations of airborne asbestos are designed to measure prevalent concentrations, that is, air levels observed under normal conditions. Higher ("peak") levels that may result from damage to asbestos-containing materials in buildings typically are not reflected in these measurements. Figure 1 provides a graphic summary of data on prevalent concentrations of airborne asbestos in three types of settings: asbestos manufacturing or application facilities before imposition of the OSHA standard in 1972, schools where asbestos-containing materials are present, and outdoor locations in urban areas. In order to facilitate comparison, all data are expressed in nanograms per cubic meter (ng/m^3) units.* The range of values within each category reflects differences in the location and strength of asbestos sources as well as variability in asbestos measurements. Concentrations above the upper limits of these ranges may occur for short periods if, for example, manufacturing equipment malfunctions, insulating material is pierced with a sharp object, or asbestos-coated surfaces are disturbed by the impact of a projectile (for example, a ball bounced against a ceiling).

Comparing the values in Figure 1, one can see that airborne asbestos levels in buildings with asbestos-containing materials can be substantially higher than outdoor levels, but significantly lower than concentrations to which asbestos workers have been exposed. Prevalent concentrations of airborne asbestos found in a sample of schools are approximately 100 times higher than outdoor concentrations. Compared with historic levels of asbestos in workplaces, airborne asbestos in these schools is lower by a factor of between 1,000 and 10,000. However, short-term peak levels in buildings may be elevated considerably, perhaps approaching dustrial levels.

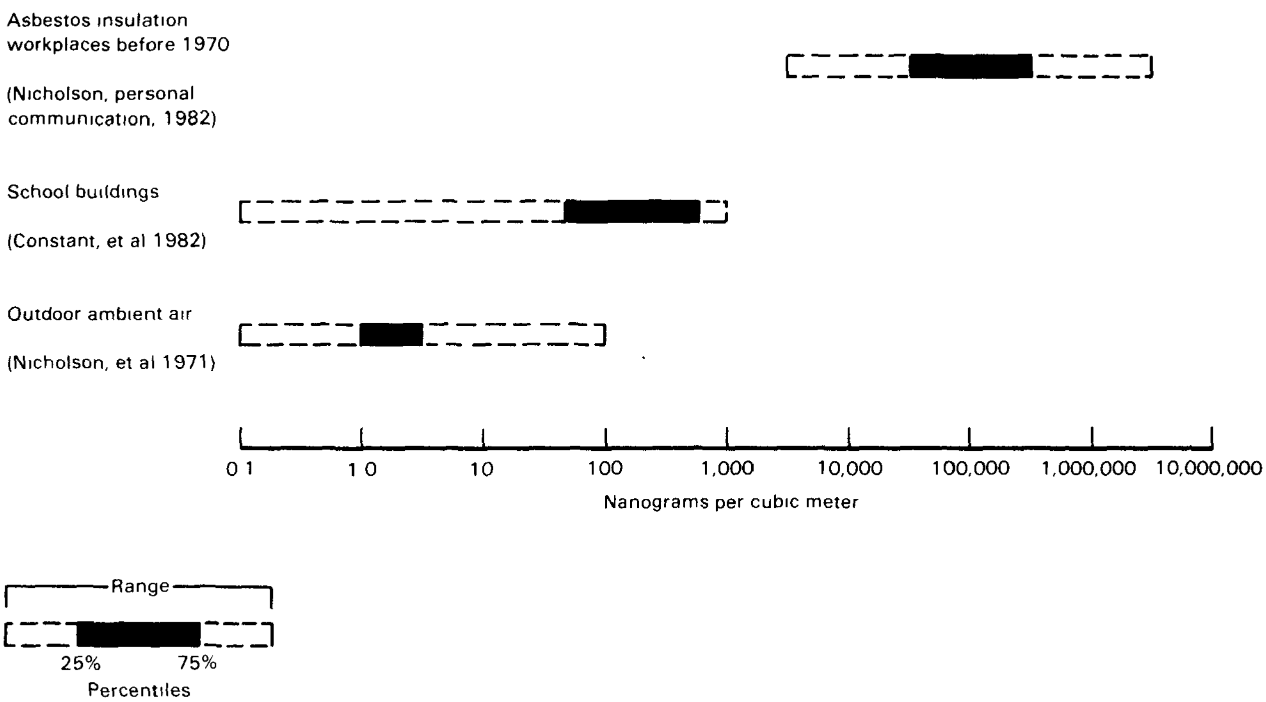
Comparison of the data in Figure 1 should be made with some caution. The estimates of concentrations in asbestos workplaces are based on measurements of airborne fibers using the measurement method specified by OSHA (phase contrast microscopy), while the levels in schools and outdoors were measured by a different method (electron microscopy). Comparisons of measurements obtained by the two methods are based on certain assumptions presented in the footnote to Figure 1. The measurement of airborne asbestos fibers is a complex subject and is discussed in more detail in Section 3.2.2.

Questions of measurement comparability notwithstanding, the presence of significant levels of airborne asbestos in buildings with asbestos-containing materials has been clearly established. The potential for exposure to asbestos by building occupants cannot be ignored. Even though exposure levels are likely to be low in comparison with industrial levels, any additional exposure above background (outdoor) levels should be avoided if possible. A prudent response by building owners requires recognition of the potential hazards and serious consideration of appropriate abatement actions.

---

*Concentrations of asbestos fibers in the air are measured in terms of either the number of fibers per unit volume (typically, a cubic centimeter) or the mass per unit volume (typically, nanograms per cubic meter). A nanogram is one-billionth of a gram. See Appendix A for a simple discussion of measurement units used for airborne asbestos concentrations.

Figure 1. Comparison of measured airborne asbestos concentrations in three settings.*



*Levels in asbestos workplaces were derived from measurements using phase contrast microscopy (PCM) while levels in school buildings and outdoors were measured using electron microscopy (EM). PCM and EM measurements are not directly comparable. PCM measures all fibers whereas EM can distinguish between asbestos and nonasbestos fibers. In addition, EM has a better capability than PCM for detecting small fibers. In order to translate the workplace PCM measurements (expressed as fiber counts) into values of asbestos mass (nanograms) that are approximately comparable to EM measurements, 30 fibers were assumed to equal one nanogram. This value is an average obtained from many comparisons of PCM and EM measurements taken at the same location (industrial settings) and time. Values for individual samples range from about 10 fibers per nanogram of asbestos to well over 100 fibers per nanogram, depending on the average size of fibers and the relative number of asbestos and nonasbestos fibers in the air (Versar 1980 and William Nicholson, personal communication, 1982).

CHAPTER 2 — DEVELOPING A CONTROL PROGRAM

An asbestos control program for schools and other buildings begins with an investigation for evidence of asbestos-containing materials. If the presence of asbestos is confirmed, the program proceeds with an assessment of the need for corrective action, the implementation of asbestos control measures, and, if necessary, periodic reassessment.

This chapter addresses issues related to the organization and management of an asbestos control program for buildings where the presence of asbestos is suspected. Based on the experience of several school boards over the last few years, the development and execution of a successful asbestos control program involve the following activities:

Establishing Responsibility: An asbestos program manager is designated and is given the responsibility for directing and managing control program activities. The program manager obtains guidance from the appropriate EPA Regional Asbestos Coordinator (RAC) and becomes familiar with the key organizational, procedural, and technical elements of an asbestos control program.

Planning: A program plan is developed to guide and schedule the program activities.

Selecting Advisors and Obtaining Advice: The program manager identifies technical advisors and experts who will assist in plan development and implementation.

Implementing Corrective Measures: Corrective measures may be implemented by in-house staff or by a contracting firm. If in-house staff or persons initially unfamiliar with methods of asbestos control are to participate, they must be thoroughly trained and provided with adequate protective devices. If the need for corrective action involves the employment of abatement contractors, serious attention should be given to contractor selection and project surveillance.

Recordkeeping: Detailed records of all program activities, decisions, and analyses are maintained.

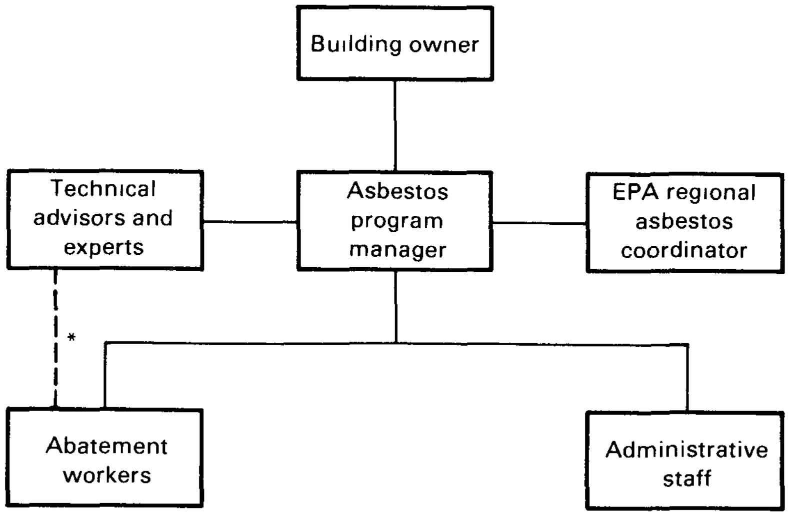
Figure 2 is a chart of the general control program organization.

This chapter emphasizes planning and management. The activities listed above are discussed in that context. Chapters 3 and 4 discuss important technical issues involved in executing specific aspects of the program plan.

Since asbestos-containing materials are present in buildings in many forms, it is important for this discussion to identify those that constitute the greatest potential hazard.* Most efforts to reduce asbestos levels in buildings have focused on friable materials, that is, materials that can be crumbled, pulverized, or reduced to powder by hand pressure. (The Asbestos-in-Schools rule issued in May 1982 addresses only friable asbestos-containing materials.) Friable materials are generally believed to have a higher potential for fiber release than nonfriable materials. As a result, the starting point for most asbestos control programs is an inspection for friable materials in the building. Typically, friable materials have been sprayed or troweled onto surfaces for fireproofing, insulation, soundproofing, or decoration. Nonfriable materials cannot be ignored because they also may release fibers if disturbed or mechanically altered during building repair or remodeling, or if damaged during normal

*Asbestos-containing materials may be found in schools and other buildings in the form of cement products, acoustical plaster, fireproofing textiles, vinyl floor tiles, thermal insulation, and other construction materials. Descriptions of these and other asbestos-containing materials appear in Appendix C.

Figure 2. Control program organization.



*The technical expert(s) may be delegated authority to direct and/or monitor asbestos abatement activities

building use. However, the need for corrective action is focused on friable asbestos-containing materials. Documentation and surveillance are recommended for nonfriable materials which contain asbestos. Figure 3 shows pictures of both friable and nonfriable asbestos-containing materials in buildings.

2.1 Establishing Responsibility

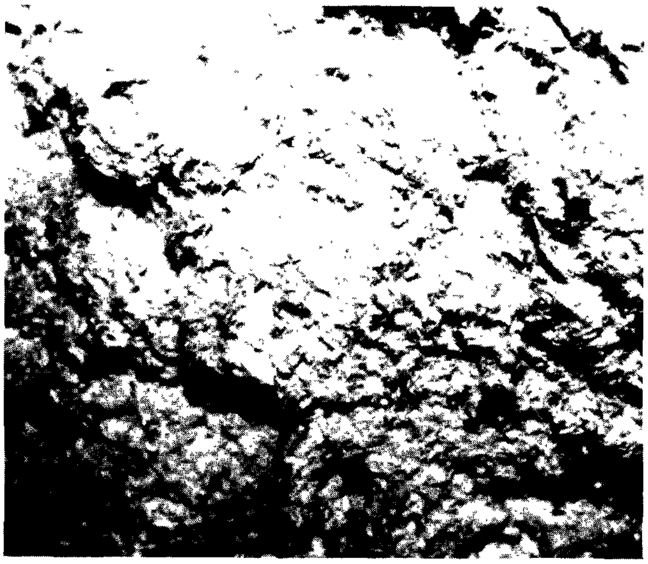
Responsibility for potential asbestos exposure in a building rests with the building owner. In schools, this responsibility belongs to the governing official(s) of the local education agency. Typically, the task of organizing the control program is assigned to an individual with responsibility for building construction or maintenance. This person, the asbestos program manager, should become familiar with general procedures for detecting asbestos, methods for assessing exposure potential, and techniques for controlling asbestos release. The office of the EPA Regional Asbestos Coordinator (RAC) is a good starting point for obtaining information on asbestos in buildings. As the building owner's representative, the program manager guides the entire control program and is the focal point for communication with the building owner.

2.2 Planning

The asbestos program manager first determines if asbestos is present and outlines a plan for a comprehensive control program. A plan for a control program may include the following activities:

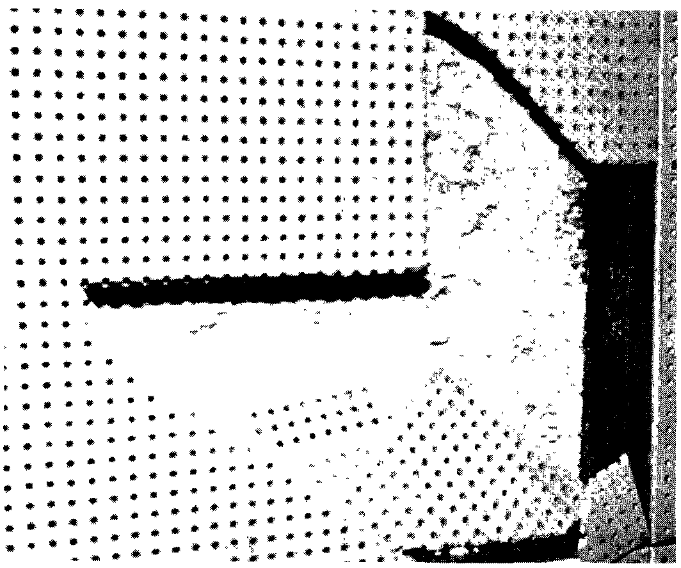
- Inspect, sample, and analyze (by polarized light microscopy [PLM]) friable material to detect asbestos (see Section 3.1).*
- Assess the need for corrective action at sites with asbestos (see Section 3.2).

*Since disturbance of nonfriable asbestos-containing materials should be avoided, sampling and analysis are usually limited to friable materials. Requirements for asbestos identification in the Asbestos-in-Schools rule apply to friable materials only.



Friable, fluffy sprayed-on material

Friable, cementitious sprayed-on or troweled material (acoustical plaster)



Nonfriable wallboard with friable sprayed-on material behind

Friable material on beam with nonfriable pipe insulation below

Figure 3. Examples of friable and nonfriable asbestos-containing materials found in buildings.

- Implement interim control procedures (see Section 3.3).
- Evaluate and select among alternative abatement or special operations and maintenance measures (see Sections 3.3 and 3.4).
- Develop a bidding process if an abatement contractor is needed (see Section 2.4).
- Direct and/or monitor abatement activities, and evaluate contractor performance for those projects undertaken by an abatement contractor (see Sections 2.4, 4.1, and 4.2).
- Monitor building maintenance activities on a continuing basis if asbestos-containing materials have not been completely removed (see Sections 2.4 and 3.3).
- Maintain records of survey results and all remedial actions (see Section 2.5).

The plan should include a list of the tasks required, a description of work practices and a time schedule for completion of each task.

The first five activities listed above focus on detecting asbestos and selecting a strategy for controlling asbestos if it is present. As noted, Chapter 3 discusses these activities in detail. Other activities involve program management and surveillance. General guidance for these activities is given in the remaining sections of this chapter. Criteria for determining abatement project completion are discussed in Chapter 4.

2.3 Obtaining Advice

In developing and implementing the program plan, the program manager should identify persons within the school system or affiliated with the building owner who are familiar with structural or operating characteristics of the building under consideration, or who have specialized legal, medical, or communications expertise. Included among this group of technical advisors are:

- school board or building architects;
- custodial staff supervisors;
- heating and ventilation engineers;
- loss control specialists (especially where catastrophic insurance is in force);
- the building owner's attorneys (and other legal specialists as needed);
- medical specialists; and
- public relations specialists.

Expert assistance in detecting the presence of asbestos, in assessing the need for corrective measures, and in undertaking control actions may also be needed. This expertise may be provided by a person already working with the building owner who has or can gain experience in asbestos assessment and control, or by an outside consultant, such as an engineer, industrial hygienist, or architect. The technical expert may be asked to participate in program planning prior to determining if asbestos-containing materials are present. If the program manager is confident about implementing the method offered in previous EPA guidance for inspecting, sampling, and analyzing to detect asbestos (Lucas, et al 1980a and 1980b, and the FEDERAL REGISTER [47 FR 23360]), then the assistance of the technical expert may be postponed until it is determined that asbestos is present. In either case, the expert should be prepared to participate in developing the control program plan.

The expert also may be asked to assist in assessing the need for corrective action and in selecting among remedial measures. If the selected control strategy requires an abatement contractor, the expert could help select a contractor and could monitor contractor performance. If this option is selected, the expert should have no affiliation with the abatement contractor in order to avoid a possible conflict of interest.

Architects often are selected as technical experts because they are familiar with the legal and technical aspects of building construction and contract administration. This knowledge is valuable if an abatement contractor is ultimately employed. Many school boards have chosen to delegate to the architect the entire responsibility for writing contract specifications, monitoring work performance, and determining successful abatement (see Section 2.4 for a discussion of abatement contracting). However, it must be noted that not all architects are experienced in assessing asbestos problems or developing control plans. It thus may be desirable to utilize other experienced advisors and experts to complement the architect. Alternatively, asbestos experts or technical advisors may learn enough about contracting procedures to take on the responsibilities of directing the abatement contractor.

Regardless of which option is selected for obtaining expert advice and assistance, the quality of the service obtained is critical. If an outside consultant is hired, chances for obtaining high quality services will be improved if the following suggestions are followed:*

- Require evidence of experience and/or training in assessing asbestos problems and in asbestos control. Check references, especially other building owners for whom the consultant has worked.
- Prepare a job description to include daily worksite inspections while an abatement project is in progress. The technical expert should check for compliance with contract specifications by the abatement contractor.
- Pay the consultant on a fixed price or simple time basis rather than a percentage of total abatement project cost (as is common for architects). This would further reduce concerns about conflict of interest.

As noted previously, the Regional Asbestos Coordinators are primary sources of information.† Through their experience, they offer guidance on developing and managing asbestos control programs. The RACs also can help identify technical consultants, laboratories for performing asbestos analyses, firms to conduct abatement actions, and other building owners in their region with experience in asbestos control. The RACs also may provide training for persons involved in asbestos-related activities. An excellent example of a comprehensive asbestos control training program is the one developed by EPA's Region IV Office in conjunction with The Georgia Institute of Technology.

2.4 Implementing Corrective Measures

Once corrective measures have been selected, the program manager must decide on the method of implementation. In general, two options are available: in-house staff or outside abatement contractors. Where the corrective action is a set of special operations and maintenance procedures designed to reduce and maintain low airborne fiber levels, the

*The American Institute of Architects' "Standard Form of Agreement Between Owner and Architect" also may prove useful where an architect or other third party is primarily responsible for overseeing abatement. A copy of this publication can be obtained from AIA, 1735 New York Avenue, Washington, DC 20006.

†Addresses of the 10 RACs can be found in Appendix B.

in-house custodial staff is likely to implement it.* If asbestos removal, enclosure, or encapsulation is chosen as a control measure, it is extremely important to employ persons trained or experienced in handling asbestos. Any effort to reduce asbestos exposure levels by treating asbestos-containing material entails a hazard to abatement workers and building occupants alike. Removal, enclosure, or encapsulation of this material may involve large-scale release of fibers. Properly conducted by trained workers, these control activities can be highly successful. But if these activities are undertaken by workers having no asbestos experience, and without strict adherence to recommended operating procedures, the airborne asbestos concentration levels experienced after abatement may rise above preabatement levels.

When an abatement contractor is to be employed, the program manager (or the technical expert) should consider taking the following steps to increase the likelihood of successful asbestos abatement:

- Establish contract specifications tailored to individual projects;
- Conduct a thorough evaluation of contractors prior to contract award;
- Require persistent on-site surveillance of contractor performance during abatement activities; and
- Establish criteria prior to the start of abatement work for determining successful project completion.

EPA's guidance for treating asbestos in schools, published in 1979 (USEPA 1979, Sawyer and Spooner 1979), provides a starting point for preparing project specifications. EPA and OSHA regulations and recommended work practices for asbestos removal, enclosure, and encapsulation are described briefly in those publications.

EPA's experience since 1979, primarily with school districts, has raised concerns about adequate contractor performance. In several cases, an apparently competent contractor prepared a responsive and price-attractive bid only to prove incapable of following or unwilling to follow contract specifications after being awarded the contract. The following suggestions are offered to help building owners avoid these situations and to increase the likelihood of a successful project.

- Contractors should be required to show evidence of experience and/or training in asbestos abatement. Check references and ask for names of other building owners for whom contract bidders have worked.
- Rather than simply noting that the contractor is responsible for complying with all EPA, OSHA, and state/local regulations, require prospective bidders to describe their worker protection and site containment plans in detail. Ask for their standard operating procedures and employee protection plans, with specific reference to their OSHA *medical monitoring and respirator training program. The information* obtained is extremely useful in distinguishing truly competent firms. An oral discussion is recommended to further demonstrate the contractor's capabilities and understanding of the problem.
- Insist on proof of adequate liability and property (builder's risk) insurance from all prospective bidders. A performance bond should also be required of the contractor before work begins.
- Ask for detailed written descriptions of how bidders will satisfy the project specifications. Use these to judge the competence of bidders and, subsequently,

*Some school systems have trained a centralized cleanup team for periodic deployment in individual school buildings.

the quality of work. The technical expert should be actively involved in evaluating bids. Information in Chapter 3 on specific problems with each abatement technique should be useful in evaluating bids.

- Be specific about what constitutes successful job completion. A thorough visual inspection to ensure adequate cleaning is an absolute necessity; air monitoring also should be considered (see Chapter 4 for a discussion on determining project completion).
- Encourage active competition for abatement contracts. Wide variation in price among contractors is the rule. Remember that successful abatement, not cost minimization, is the goal. A premium may well be justified to help assure success.

These suggestions are based on the past few years of experience with asbestos abatement in schools. Recall that the EPA Regional Asbestos Coordinator is available as a source of additional information and suggestions. The RAC should be contacted early in the process of developing a control plan.

2.5 Recordkeeping

Regardless of the corrective actions taken, the asbestos program manager should prepare thorough and detailed records of all findings and abatement actions. These should be retained in a permanent file. Information on the location and nature of any remaining asbestos-containing materials is critical to protecting building occupants and to controlling these materials during remodeling or building demolition.

EPA's Asbestos-in-Schools rule contains specific recordkeeping requirements. These include:

- the number and locations of samples used to determine if asbestos is present;
- a copy of the results of laboratory PLM analyses of the sampled material;
- the asbestos content of the material sampled in each area;
- a statement certifying that no friable asbestos-containing materials are present if no friable materials are found or if the tests for asbestos are negative; and
- a description of each building, indicating the location(s) and approximate area(s) in square feet of asbestos-containing materials.

In addition to information on the presence of asbestos-containing materials, the nature of potential exposure problems should be characterized and the type of abatement actions taken should be described. Specifically, this record might include:

- descriptions and photographs of the condition, accessibility, and other relevant characteristics of asbestos-containing material found in various parts of the building before corrective measures were taken (section 3.2 in Chapter 3 contains a discussion of assessing asbestos-containing materials);
- detailed descriptions of asbestos removal, enclosure, encapsulation, or other control measures applied to individual areas, including the date action was taken;
- ongoing efforts to monitor potential asbestos problems and employ special operating and maintenance practices;
- names of technical advisors and all consultants and contractors hired for asbestos-related work; and
- costs associated with all abatement actions.

CHAPTER 3 — DETECTING ASBESTOS, ASSESSING THE PROBLEM, AND SELECTING A COURSE OF ACTION

The central questions facing owners of buildings where the presence of asbestos is suspected are: (1) Is asbestos actually present? (2) If it is, how significant are existing or potential exposure problems? and (3) What control measures are needed? This chapter discusses technical aspects of the process for addressing these questions that was outlined in Chapter 2. The most significant conclusions and recommendations are summarized below.

Inspecting, Sampling, and Analyzing for Asbestos:

- Inspection and sampling procedures to detect friable asbestos-containing materials have been published in previous EPA documents. Key points are identifying homogeneous sampling areas and implementing the recommended quality assurance plan during sampling and analysis.
- Although emphasis is on detecting friable materials, the possible presence of nonfriable asbestos-containing materials must also be considered. However, nonfriable materials should not be sampled since sampling may unnecessarily release fibers.

Assessing the Need for Corrective Action:

- The condition of asbestos-containing materials and their potential for disturbance or erosion can be used to determine if corrective measures should be taken.
- Factors for assessing material condition and the potential for disburbance or erosion should be used qualitatively. Numerical scoring and index systems have not proven reliable.
- Due to technical problems and high costs, monitoring of airborne asbestos is not recommended for assessment purposes.

Control Techniques:

- Four alternative control actions should be considered: (1) asbestos removal, disposal, and replacement; (2) enclosure; (3) encapsulation; and (4) a special operations, maintenance, and reinspection program.
- The applicability and cost of each alternative will depend on the amount and condition of the asbestos-containing materials to be treated and structural characteristics of the underlying supporting surfaces.
- All control measures except the special operations and maintenance program should be undertaken only with proper work area containment and worker protection. Protection for maintenance workers also may be necessary.
- Until a control alternative is chosen, interim operations and maintenance procedures should be used to reduce levels of airborne fibers.
- A continuing program of special operations and periodic reassessment will be necessary even after asbestos-containing materials have been enclosed or encapsulated.

Decision-Making:

- It is difficult to develop a set of rules that can be uniformly applied to every asbestos control situation. Local conditions make each situation unique. However, organizing and analyzing information on (1) the condition and potential for disturbing the asbestos-containing materials, and (2) the advantages and disadvantages of control alternatives will help in selecting an effective course of action.

3.1 Inspecting, Sampling, and Analyzing for Asbestos

As discussed in Chapter 2, the first task in an asbestos control plan is to determine whether or not asbestos is present. This involves investigating building records for mention of asbestos-containing materials, inspecting the building for friable materials, and analyzing samples of friable material for asbestos. Figure 4 illustrates a logical sequence of steps for this task. First, investigate building plans, remodeling records, and other sources (such as personal knowledge) for specification of asbestos-containing materials. Information on the type and location of asbestos-containing materials will help focus the next step—inspecting for friable materials in the building. A building inspection might start with those areas where asbestos-containing materials are reported to be present and then expand to all parts of the building. If friable materials are found, they should be sampled and analyzed as discussed below.* If the presence of asbestos in the friable materials is confirmed (more than 1 percent by weight), then the assessment for corrective action is begun. If, on the other hand, no friable materials are found—or if they are found, but do not contain asbestos—document these results. A formal statement of these findings (called "negative certification" in Figure 4) is required for schools. If the investigation of building records or the building inspection indicates that nonfriable asbestos-containing materials are present, these materials should be reinspected periodically for changes in their condition.† Reinspection is especially important for friable materials that have been painted or covered with a hard wrapping (and would thus be classified "nonfriable"), such as pipe and boiler insulation. Damage or slow deterioration of the wrapping or paint could cause significant release of asbestos fibers, thus requiring a detailed assessment of the need for corrective action.

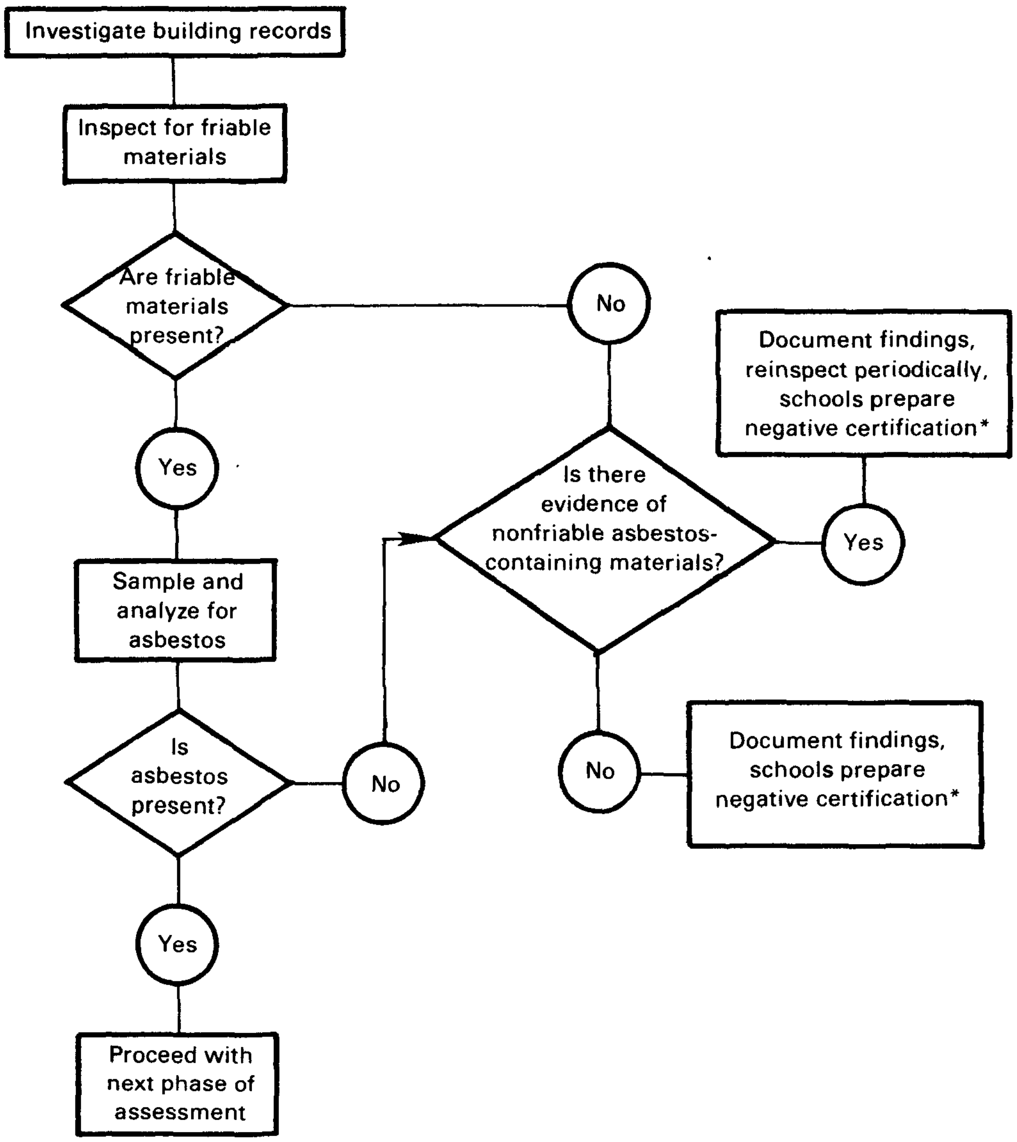
To further clarify the types of materials to be investigated in an asbestos control program, a chart showing asbestos-containing materials found in buildings is presented in Figure 5. The first level is based on the most important characteristic—friability. Materials which are friable and contain asbestos are likely to be sprayed or troweled onto surfaces in either fibrous or cementitious form. Nonfriable asbestos-containing materials are more diverse. As noted above, asbestos insulation on pipes and boilers is of special concern. Pipes and boilers are usually accessible to building occupants (especially custodial workers) and often are prone to damage. Pipe and boiler insulation may look like chalk, bricks, mud, or corrugated cardboard. Often these insulation materials are enclosed in a canvas, stainless steel, or plastic jacket. The boiler wrapping and pipe jackets should be carefully inspected for damage that could allow release of asbestos fibers. Other nonfriable asbestos-containing materials normally are hazardous only when cut, drilled, sanded, or removed during remodeling or demolition. Note, again, that nonfriable pipe and boiler insulation should be considered friable when damaged. Examples of friable and nonfriable asbestos-containing materials were shown in Figure 3. Figure 13 shows pictures of damaged and deteriorating pipe insulation.

---

*The Asbestos-in-Schools rule allows schools to skip the sampling and analysis steps and simply assume that any friable materials found in the building contain asbestos. The location of all friable materials must be documented and all affected parties, as described previously, must be notified.

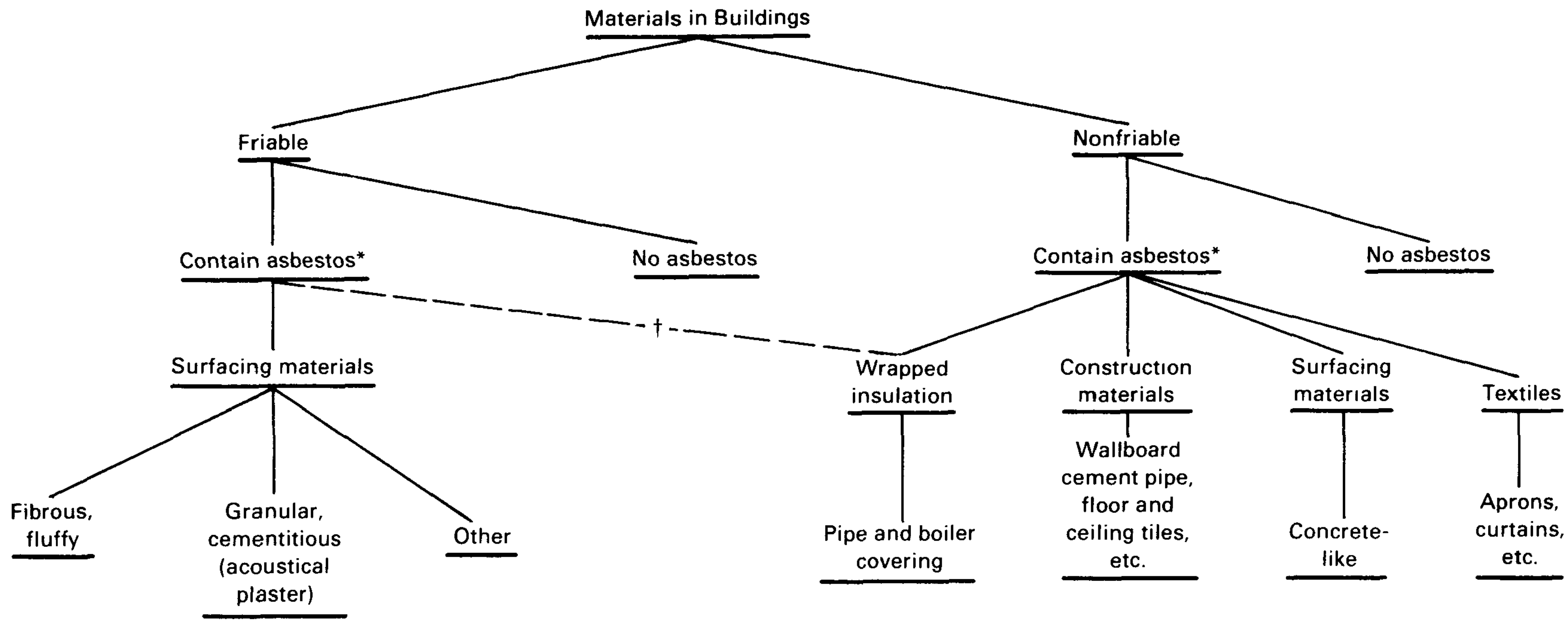
†Inspection for nonfriable materials is not required by the Asbestos-in-Schools rule.

Figure 4. Steps in investigating for the presence of asbestos.



*Negative certification is a statement certifying that no friable asbestos is present.

Figure 5. Types of building materials which could contain asbestos.



*See Appendix C for a more complete description of asbestos-containing materials.
†Wrapped insulation that is damaged may be friable.

Specific requirements for sampling and analysis in schools were given in the Asbestos-in-Schools rule (40 CFR Part 763, Subpart F). Although legal requirements for investigating the presence of asbestos apply only to schools, the procedures are broadly applicable to any building. A detailed sampling and analysis plan must be developed and implemented. Quality assurance procedures must be employed for reliable results. A recommended approach is described in the Asbestos-in-Schools rule and in "Asbestos-Containing Materials in School Buildings: Guidance for Asbestos Analytical Programs" (Lucas, et al 1980a). Key elements are provided here to help the reader understand sampling and analyzing bulk material for asbestos. (Further information on sampling and analysis is available by calling the EPA Technical Information Service, (800) 334-8571, or the Regional Asbestos Coordinators.)

- Appoint a sampling and analysis coordinator to oversee the entire sampling and analysis operation and quality assurance program. The asbestos program manager typically assumes this role.
- Identify homogeneous sampling areas of friable material. These are areas covered with material that has the same appearance and texture. If an area that appears homogeneous is known to consist of different materials, perhaps due to remodeling or building expansion, the area should be subdivided for sampling purposes. Damaged or exposed parts of pipe and boiler insulation should also be considered distinct "sampling areas."
- Collect at least three core samples of material in each homogeneous sampling area. The method of random selection should be used to identify locations where samples will be taken. Random selection will assure an established statistical level of confidence in the estimates of asbestos content. (Specific procedures for designing the sampling plan are given in the EPA guidance document referenced above [Lucas, et al 1980a] and in a companion document [Lucas, et al 1980b].) Note that pipe and boiler insulation in good condition should not be sampled, since sampling requires breaking the insulation jacket.
- Develop a quality assurance program following recommendations in the guidance document (Lucas, et al 1980a). A key feature is the use of split samples, that is, duplicate samples from the same sampling location, to confirm laboratory analyses.
- Submit samples to a qualified laboratory for analysis. A list of laboratories that participated in the EPA quality assurance program for bulk sample analysis appears in the document noted above (Lucas, et al 1980a). The list is periodically updated. A current list and additional information on laboratory qualifications may be obtained by calling the EPA Technical Information Service, (800) 334-8571, or the RACs. The approved method of bulk sample analysis for asbestos is polarized light microscopy. A supplementary method, X-ray diffraction, may be required in certain cases. The laboratory report should include:

  (1) sample identification number;
  (2) analytical method used;
  (3) sample appearance and treatment;
  (4) type and percent of both asbestos and nonasbestos constituents;
  (5) method of quantification; and
  (6) analyst's name.

  The type of asbestos mineral present may be important information when the asbestos-containing material is eventually removed.
- To determine whether the samples have more than 1 percent asbestos, the laboratory results should be interpreted using statistical procedures described in previous EPA guidance (Lucas, et al 1980a).

3.2 Assessing the Potential for Exposure to Asbestos

If the sampling and analysis of bulk material show that asbestos is not present, there is no need for further action except to document the findings. A positive finding indicates the need for a thorough assessment of the potential for exposure to airborne asbestos, followed by the consideration of appropriate corrective measures. This section addresses various approaches to assessing the need for corrective action.

3.2.1 Principles of Fiber Release, Suspension, and Transport

As noted in the previous section, asbestos fibers can be released spontaneously from asbestos-containing material in the normal process of the material's aging and deterioration. This process can be accelerated by air movement or vibration. In addition, a dramatic increase in the rate of fiber release may accompany disturbance of asbestos-containing material. Once released, either by deterioration or by sudden damage, asbestos may remain airborne for extended periods of time. The small size of asbestos fibers facilitates their suspension by regularly fluctuating air currents. Even when the fibers eventually settle during quiet periods (for example, weekends), they are readily re-suspended by the normal activities of building occupants and custodial and maintenance personnel.

Asbestos fibers are transported from the point of release to other locations within the building largely via airstreams from air circulation equipment. Measurements of asbestos concentrations in school buildings suggest that fiber levels can be elevated throughout a building even though the area of fiber release is restricted to a few rooms (Constant, et al 1982).

3.2.2 Estimating the Potential for Fiber Release

One approach to assessing the need for corrective action is to estimate the likelihood of fiber release from materials in which asbestos has been confirmed. This approach uses subjective assessments of asbestos-containing materials, and assumes relationships between airborne asbestos levels and characteristics of these materials. The approach has the advantage of practicality and, in certain circumstances, may reveal the potential for future fiber release even when actual levels of airborne asbestos are relatively low.

The following sections discuss the use of various factors to assess characteristics of asbestos-containing materials. Their use both as qualitative descriptors and in numerical rating schemes is evaluated.

3.2.2.1 Proposed Exposure Indices

Several lists of assessment factors have been proposed for the purpose of estimating the potential for fiber release from asbestos-containing materials. These include the EPA factors as presented in Chapter 7, Part 1, of the initial EPA guidance document (USEPA 1979a), the U.S. Navy's asbestos risk evaluation procedure (Lory 1980), the Toronto Board of Education index* (Pinchin 1982), and the U.S. Department of Education's asbestos scoring system as published in the FEDERAL REGISTER (46 FR 4536). Each list contains factors relating to the current condition of the material, the amount of asbestos present, and the vulnerability of the material to physical damage and erosion by air movement. Guidance is provided for scoring

*This is also known as the "modified Ferris Index."

each factor and combining those scores into an overall index.* In this way, asbestos-containing materials in various locations within a single building or in different buildings can be evaluated and compared. The value of these indices rests on the validity of the assumed relationships between factor scores and actual (or potential) concentrations of asbestos in the air.

Several tests of these relationships have been conducted. The EPA-sponsored study of an urban school district (Constant, et al 1982) is the most recent and comprehensive. Of the various EPA factors which were assumed to be positively correlated with measured levels of airborne asbestos, only two were confirmed: the presence of water damage and the proximity of the material to an airstream created by the ventilation system. For several factors (degree of friability, percent asbestos content, degree of activity), a direct relationship with airborne asbestos was not confirmed. Other factors (accessibility, degree of exposed surface area, condition of the material) did not receive a fair test, typically because little or no variation in scores was observed in the schools. Tests conducted by other investigators (Sebastien, et al 1982 and Pinchin 1982) using combined factor scores (that is, the index values) likewise produced little correspondence between ratings and measured air levels. Tests using the U.S. Navy risk procedure index and the Toronto Board of Education index fared no better (Pinchin 1982).

These findings indicate that numerical ratings derived from subjective assessments of fiber release potential are not reliable indicators of measured airborne asbestos levels. However, selected assessment factors may help identify a high potential for future fiber release. Employed in a qualitative manner, some factors also may help distinguish among major categories of asbestos problems. Selection and use of these factors is discussed in the following section.

3.2.2.2 Usefulness of Individual Assessment Factors

The results of the hazard index evaluation studies emphasize the complexity of the fiber release process. Some proposed factors focus on conditions which are necessary but not sufficient for fiber release. A few relate to the probability of release given other necessary conditions, and thus gauge future rather than current problems. Others refer to similar or highly correlated features of asbestos-containing materials and should be combined. As a result, the use of the EPA factors to assess potential fiber release has been re-evaluated.

Table 1 displays the assessment factors judged most useful as a result of this re-evaluation. The first three individual factors focus on the current condition of the asbestos-containing material. If water damage, physical damage, slow deterioration, or delamination of the material is evident, then fiber release has occurred, is occurring, or is likely to occur in the future. Evidence is obtained from the appearance of the material and from the presence of broken or crumbled material on the floor, tables, or other horizontal surfaces. Factors under the second heading reflect the potential for fiber release due to disturbance or erosion. Exposed and highly accessible materials in areas frequented by building occupants or subject to maintenance activities are more vulnerable to physical damage than materials in other locations. In this category are materials subject to vibration from mechanical equipment, sound, or athletic activities. Examples include materials near a gymnasium or band room, or materials in buildings near an airport or highway. Likewise, asbestos-containing materials

*Although the EPA guidance document (USEPA 1979a) does not describe scoring procedures, a scoring routine known as the EPA "algorithm" was developed and appeared in the advance notice of proposed rulemaking for the Asbestos-in-Schools rule published in the FEDERAL REGISTER (44 FR 54676).

Table 1. Organization of Factors for Assessing Fiber Release Potential

Condition of asbestos-containing material

- Evidence of deterioration or delamination from the underlying surface (substrate)
- Evidence of physical damage
- Evidence of water damage

Potential for disturbance or erosion

- Proximity to air plenum or direct airstream
- Exposure (i.e., is it visible), accessibility (to building occupants and maintenance personnel), and the degree of activity (air movement, vibration, movement of building occupants)
- Change in building use

located in an air plenum or near a forced airstream are likely to suffer surface erosion. In addition, fibers released into an airstream may be transported to other parts of the building, possibly increasing the number of people exposed. A change in building use may cause changes in several of the other factors. Figures 6 and 7 illustrate several characteristics of asbestos-containing materials addressed by these factors.

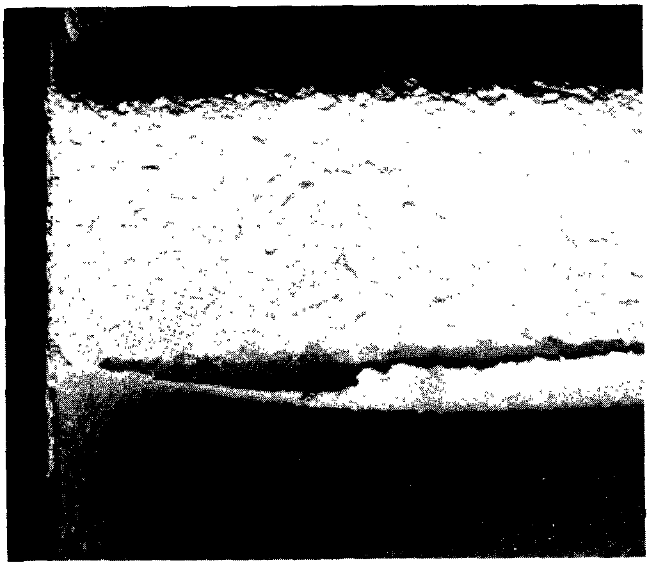
Friability and asbestos content are two factors discussed in the initial EPA guidance document (USEPA 1979) that do not appear in Table 1. Friability has already been discussed in the context of inspecting for asbestos-containing material (Chapter 2). Since only material determined to be friable needs to be sampled and analyzed, using friability for assessment at this stage would be redundant. Asbestos content may still be important in some situations, but this factor proved highly unreliable as an indicator of airborne asbestos concentration in the previously mentioned EPA validation study (Constant, et al 1982). Substantial fiber release apparently can occur in damaged or deteriorating materials, even where asbestos content is low.

Detailed descriptions of each factor in Table 1 are given in Appendix D. The information there should assist the evaluator in judging the condition and exposure or disturbance potential of individual sites.

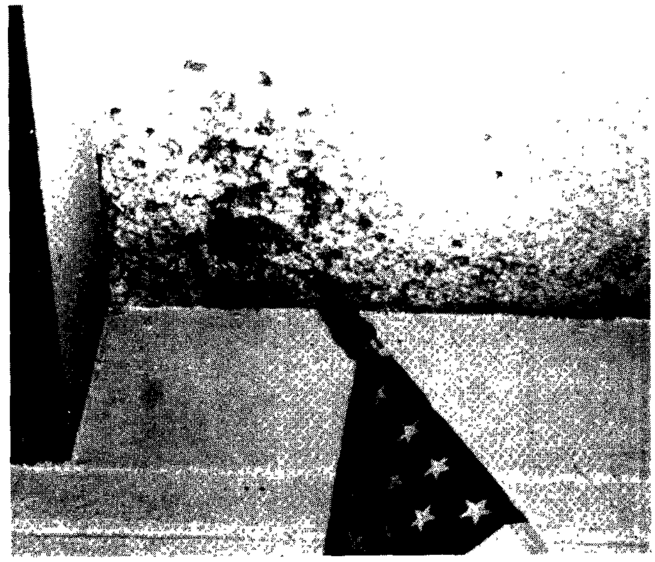
The interpretation of information from an assessment of fiber release and its use to reach decisions on abatement strategies is discussed in the last section of this chapter (Section 3.4). The factors in Table 1 are expressed in a way which fosters a "yes" or "no" type of response. The use of "yes" and "no" responses eliminates the need to rate and score each factor and provides a less ambiguous basis for decision-making.

3.2.3 Measuring Airborne Asbestos

Another proposed approach to assessing the need for corrective action is to measure asbestos fibers in the air. At best, this approach provides information only on current asbestos



Delamination from a beam

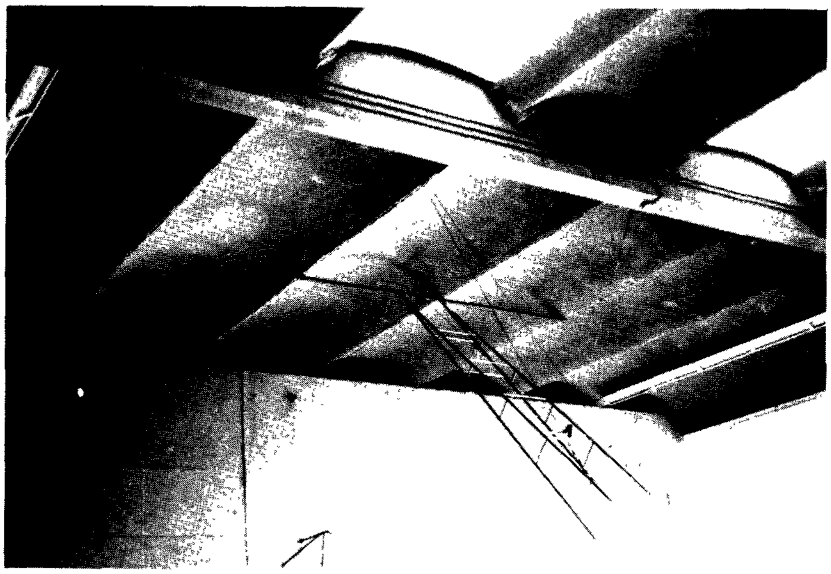


Physical damage to ceiling material from a flagpole

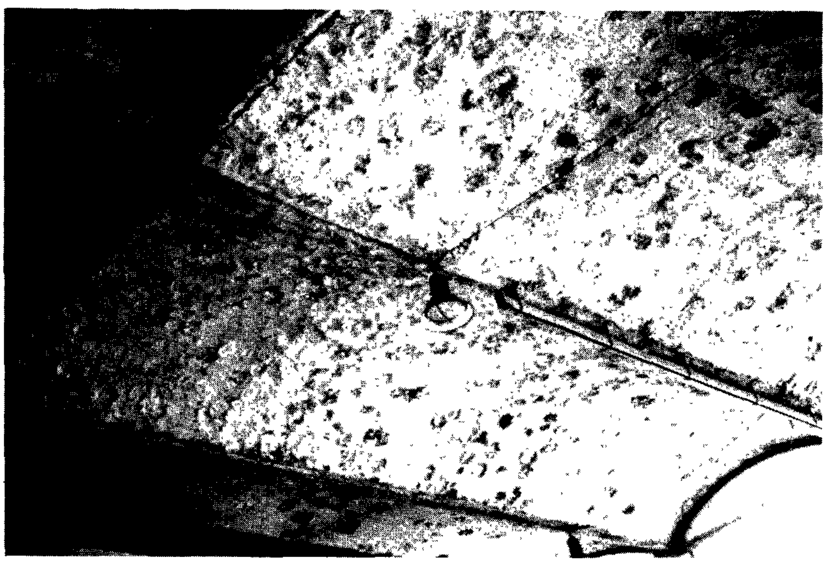
Airstream erosion from a heating vent

High activity level near friable asbestos

Figure 6. Example assessment characteristics of asbestos-containing materials.



Ceiling of a gymnasium in an elementary school
(no basketball marks)



Ceiling of a gymnasium in a high school showing evidence of damage from basketballs thrown by students

Figure 7. An example of the effect of a change in building use.

contamination and no information about the potential for fiber release and future air levels. Moreover, the use of air monitoring as an assessment tool involves substantial technical and economic problems which limit its use even for determining current levels of contamination.

As noted in Chapter 1, a list of procedures (protocol) for measuring asbestos in industrial settings has been developed by the National Institute for Occupational Safety and Health (NIOSH) in connection with the OSHA asbestos exposure standard. The NIOSH protocol employs phase contrast microscopy (PCM) for asbestos measurement. The major shortcomings of PCM are that it cannot distinguish between asbestos and nonasbestos fibers or resolve fibers with diameters less than 0.3 micrometers.* In addition, the NIOSH measurement protocol is not designed to count fibers shorter than 5 micrometers. Many airborne fibers in buildings with asbestos-containing materials are likely to have dimensions which fall outside these limits. In addition, fibers from carpets, clothing, hair, paper, books, and many other sources are likely to be present. As a result, PCM analyses of air inside these buildings could be highly misleading.

Methods for measuring small as well as large fibers and for distinguishing asbestos from nonasbestos fibers have been developed and used in various research studies. They use electron microscopy (EM) (specifically, transmission electron microscopy) to measure fibers, and both chemical and crystallographic analyses to identify asbestos minerals.† Air sampling procedures involve sampling at several sites for extended periods and, frequently, collecting several samples at each site. EPA has used these sampling procedures and EM under experimental conditions to establish baseline asbestos levels in various indoor and outdoor settings, and, as discussed above, to validate subjective rating approaches to assessing fiber release. Technical bulletins will be issued by EPA as air sampling and EM protocols are refined. Even then, the difficulty of sampling in occupied buildings and the number of samples needed to detect peak as well as prevalent airborne levels may preclude the use of air monitoring for routine assessment. The cost of EM analysis is high (about $500 per sample), and few laboratories are qualified to perform it. Given these limitations, EPA does not recommend the use of air monitoring for assessment purposes at this time.

3.3 Asbestos Control Measures

Developing and implementing an effective strategy to correct asbestos exposure problems requires detailed information on the applicability and relative costs of alternative control measures. New information on these subjects is presented in this section for each of the four generic approaches to asbestos control: (1) material removal, (2) material enclosure, (3) material encapsulation, and (4) special operations and maintenance practices combined with periodic reassessment of asbestos-containing materials. These approaches are applicable both to material sprayed or troweled on surfaces and to pipe and boiler insulation. However, control problems created by the two categories of asbestos-containing materials are different enough to warrant separate treatment here.

3.3.1 Control Alternatives for Material Sprayed or Troweled on Surfaces

Although each of the four approaches to asbestos control is a distinct alternative, they share several features. The first is the need to conduct a detailed inspection of both the asbestos-containing material to be treated and the underlying surface. Such an inspection should be

---

*A micrometer is one-millionth of a meter. See Appendix A for a simple discussion of measurement units used to describe and measure asbestos fibers.

†A provisional protocol for EM measurement of asbestos has been developed by EPA (Samudra, et al 1977).

undertaken for each separate homogeneous area of asbestos-containing material, usually a single room, hallway, or central space. (Recall the cautions noted previously about the possibility of seemingly homogeneous areas being composed of different materials and thus requiring separate inspection.) It is especially important to inspect above a suspended ceiling with lay-in panels since this may reveal otherwise hidden material (see Figure 8).

The following information should be collected:

- size of the area, since this will affect the cost of asbestos control;
- type of ceiling construction if the ceiling is coated (for example, concrete joist and beam, concrete waffle slab, steel beam or bar joist, suspended metal lath, suspended lay-in panels, tile, metal, corrugated steel), since different construction types present different control problems;
- ceiling height, which may determine the practicality of enclosing the material;
- type of wall (for example, smooth or rough concrete, block or brick, plasterboard), which may indicate whether an encapsulant is needed if the material is removed;
- thickness of asbestos-containing material and variation in thickness, since encapsulants should not be applied to thick material.

Photographs also may be desirable for documenting the current condition of asbestos-containing material. A building evaluation form developed by EPA's Region VII Office is included in Appendix E for illustrative purposes.

A second common feature of the four approaches to asbestos control is the need for worker protection during control activities. Worker protection depends on the strict use of NIOSH-approved respirators. The OSHA standards specify the use of three different respirators, depending on the expected concentration of fibers in the work area: a half-face mask with either a single-use or replaceable filter, a full-face mask with replaceable filter and a pump to assist breathing, and a full-face mask with a self-contained or remote air supply. NIOSH now recommends that the first type of respirator not be used, because it does not seal properly around the face, nor has it (or any other type) been tested for effectiveness specifically against asbestos fibers.* Supplied air (type "C") units offer the most protection. Respirators are required for asbestos removal. They are highly recommended for the other control measures, since enclosure and encapsulation activities may produce fiber levels as high as or higher than those created during asbestos removal.

A third common feature is that an aggressive program of interim control should be instituted once the level of exposure or exposure potential has been assessed and before a permanent control program begins. Consider the following program measures:

- Carpets should be steam cleaned or vacuumed with a high efficiency particulate air (HEPA)-filtered vacuum cleaner.
- Contaminated books and furniture should be cleaned with HEPA-equipped vacuum cleaners, or dusted in the manner described below.
- Dusting and mopping should be done with wet or damp cloths and mops. These should be discarded in sealed plastic bags according to EPA regulations for asbestos removal and disposal. Workers should be encouraged to wear a respirator as a precautionary measure.

---

*A letter setting forth NIOSH's concerns about these respirators was sent to respirator manufacturers on August 25, 1980. A copy of this letter appeared in the December 1980 issue of the *Journal of the American Industrial Hygiene Association.*

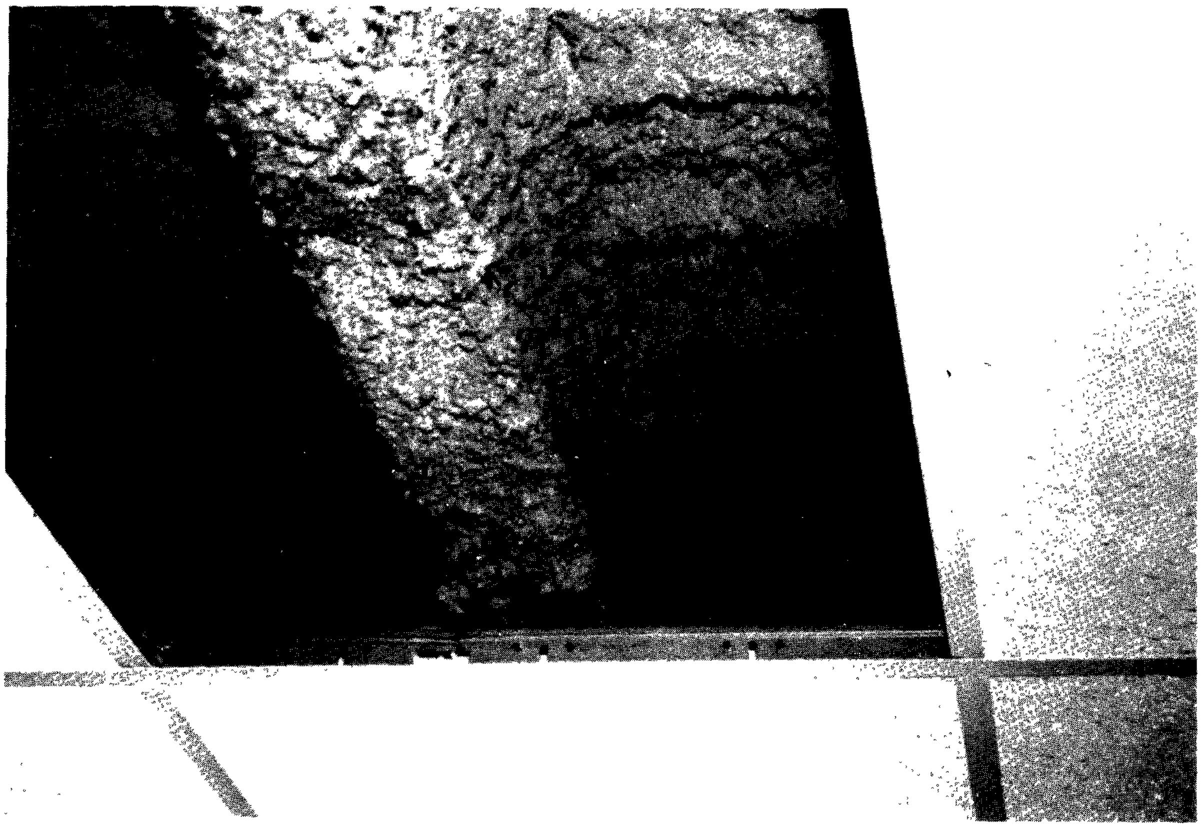


Figure 8. Asbestos-containing material located above a suspended ceiling

- When filters in a central air ventilation system are replaced, they should be treated as asbestos-contaminated waste. That is, they should be sprayed with a light water mist before removal and then sealed in plastic bags for disposal.
- Building occupants and maintenance workers should be cautioned about further damaging the asbestos-containing materials (for example, by hanging plants or mobiles from the ceiling, rewiring electrical circuits, or installing new fixtures).
- Maintenance people should be warned about disturbing suspended ceilings or other areas where fibers collect. They should also be told not to patch or repair damaged material before assessment of alternative abatement techniques.

Fourth, proper work area containment is highly recommended for all abatement techniques except special operating and maintenance practices. Once abatement work begins, all uninvolved persons should be kept out of the area. Containment typically means construction of barriers with 6 mil polyethylene plastic sheets joined with folded seams, and with sealing tape at the seams and boundaries. Some contractors have experienced problems in securing plastic sheets to walls. Thinner sheets or a better attachment system (for example, stapling and taping sheets to furring strips fastened to walls) may be required. (Figure 9 shows the construction of a typical containment system.) Air locks and worker decontamination facilities with showers are recommended.* So, too, are negative air pressure systems, as described in Section 3.3.1.1 below. Without adequate containment, increased exposure for building occupants is likely. Abatement activities should be conducted during vacations or other times when few people are in the building.

Detailed descriptions of work area containment and worker protection can be found in Part 1 (Chapter 9) and Part 2 (Section 2, Part II) of the initial EPA guidance on asbestos in schools (USEPA 1979, Sawyer and Spooner 1979). The above comments are reminders of general requirements. They also update previous guidance on respirators and the need for work area containment in enclosure and encapsulation operations. Technical bulletins on work area containment will be published in the future.

Regardless of the abatement measure selected, a rigorous post-project cleanup is necessary. This should include wet mopping of all horizontal and vertical surfaces in the work area. (Again, wet mopheads and cloths should be discarded in sealed plastic bags and treated as asbestos-contaminated waste.) Cleaning of surfaces outside the work area is highly recommended as a precautionary measure. Two cleanings—the second after suspended fibers have settled over several days—will provide better assurance of fiber reduction than a single cleaning.

3.3.1.1 Removal, Disposal, and Replacement

Many asbestos abatement experts believe removal of asbestos-containing material is the only final and satisfactory solution to the problem of asbestos exposure. Competently performed, with adequate protection for workers and building occupants, removal can eliminate all potential for exposure. On the other hand, removal may be more complicated and cost more initially (although not necessarily in the long run) than other abatement measures.

The general approach to removal of asbestos-containing material was presented in the initial EPA guidance documents, Chapter 8 of Part 1 and Section 4, Part II of Part 2 (USEPA 1979, Sawyer and Spooner 1979). (Figure 10 is a photograph of a typical removal project.) Key features outlined in the EPA documents include:

---

*OSHA decontamination requirements specify worker change rooms as a minimum provision for asbestos removal projects.

Figure 9. Construction of containment barriers.

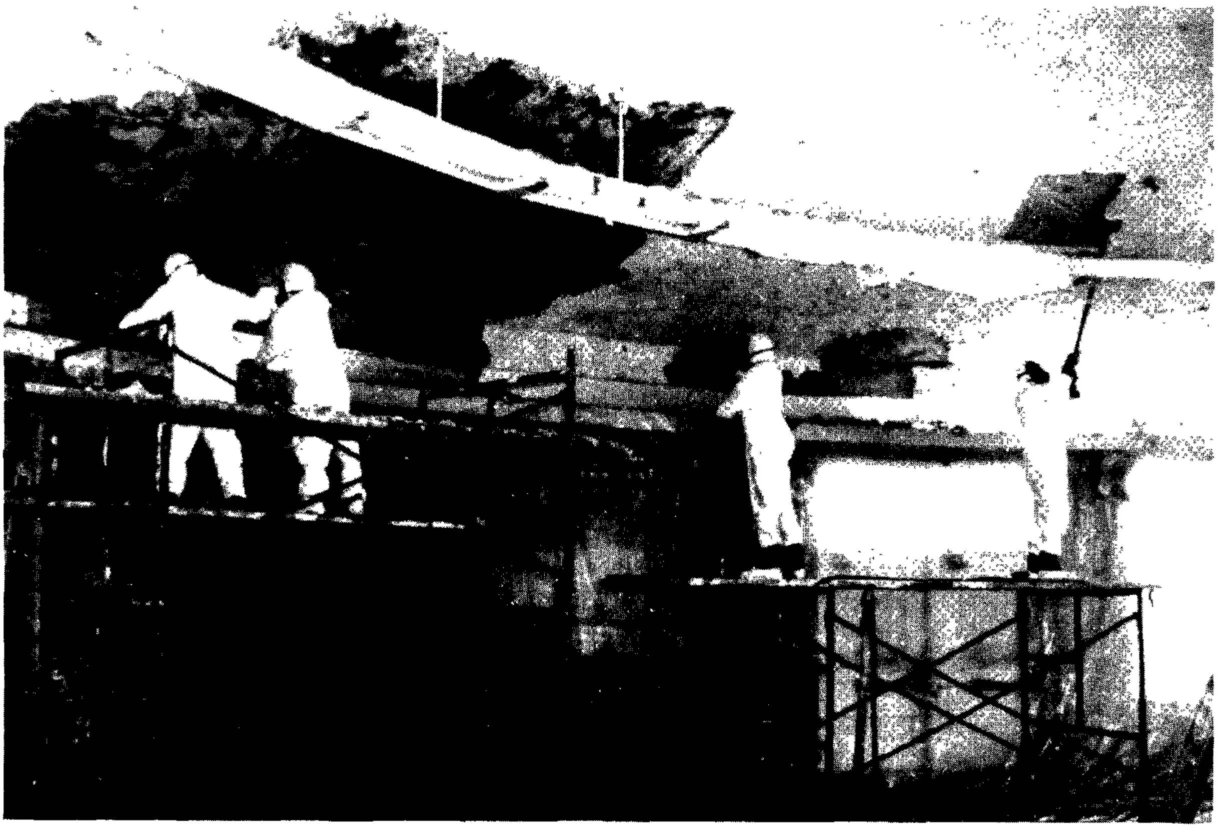


Figure 10. An asbestos removal project.

- Removal of all types of asbestos except amosite must be initiated only after the material is treated with a solution of water and a wetting agent to reduce fiber release. Some types of amosite-containing materials will not adsorb either water or water amended with the wetting agent suggested by EPA (50% polyoxyethylene ester and 50% polyoxyethylene ether) in Part 1 of the initial guidance document (USEPA 1979). Wetting agents should be tested on the material for adsorption. If the material won't adsorb the wetting agent, a dry removal will have to be undertaken using Type C respiratory protection for the workers. EPA must approve all dry removal operations.
- Friable asbestos-containing material must be disposed of in "leak-tight containers," typically 6 mil polyethylene bags. Bags frequently are placed in 55-gallon drums for additional protection.
- OSHA procedures for worker protection and decontamination, as well as for measurement of airborne asbestos, must be strictly followed. While not required by law, EPA procedures for work area containment are likewise a prerequisite for safe removal operations (see Chapter 9 and Appendices A and B, Part I of previous EPA guidance [USEPA 1979]).

Research on asbestos removal plus EPA's experience with removal activities in schools since 1979 have pointed up several issues that require more attention when removal is the chosen course of action.

- Surveillance of work practices at the worksite by a representative of the building owner is absolutely necessary. Like any other rapidly growing industry, asbestos removal has attracted companies with varying experience and competence. Even reputable firms sometimes subcontract work to expedite jobs. Relaxed enforcement of rules and incomplete adherence to contract specifications occur all too frequently. A worksite supervisor representing the building owner, and with authority to stop removal activities whenever circumstances dictate, should be present at all times. The program manager's technical expert is a logical choice for this role.
- A breach in the containment barrier is a significant exposure hazard for building occupants and should be repaired immediately. Using negative pressure systems together with HEPA filtration (that is, low volume exhaust fans with HEPA filters) to move air from within the work area to outside the building may give some protection in the event of a breach. Appendix F contains a summary of specifications for negative air systems.
- Another problem observed at several worksites concerns dismantling of containment barriers at the end of the removal operation. Sealing tape used to attach the plastic sheets to walls and ceilings frequently cannot be removed without peeling paint from these surfaces. It may be wise to include the cost of repainting all walls (and ceilings, if appropriate) in estimates of asbestos removal costs.
- Disposal and transport of removed material has been a problem. Containers full of wet material are very heavy and difficult to transport. Spilled material both in and outside the work area has been observed. Care must be exercised in sealing and handling these containers. Disposal sites may be difficult to locate. Some states require a disposal permit before removal begins.
- Amended water (water with wetting agents) from spray operations may leak through the polyethylene sheets and damage floors, especially tile and wood. A cost-effective solution might be double plastic sheets carefully sealed.

Once removal and disposal operations are finished, the need to apply a sealant on the exposed surface must be evaluated. This is also the time to decide whether to reinsulate or resoundproof with asbestos-free materials. In general, sealants are necessary where the underlying surfaces are porous (for example, concrete blocks or slabs), since a few fibers usually remain after removal.

Cost of asbestos removal varies widely among regions and among specific jobs. For example, the cost for both removal and disposal ranges from $2 to $13 per square foot (USEPA 1980).* Sealant and insulation replacement costs are additional.

3.3.1.2 Enclosure

As the term implies, enclosure involves construction of airtight walls and ceilings around surfaces coated with asbestos-containing materials. Enclosures should be constructed with impact-resistant materials. Since the asbestos-containing materials will have to be removed when the building is remodeled or demolished, enclosure is only a temporary solution. On the other hand, carefully constructed, airtight enclosures may reduce, if not eliminate, emission of fibers within the building for its remaining life.†

Figure 11 shows a typical enclosure project. The following observations supplement the discussion in Part 2 (Section 3, Part II) of initial EPA guidance (Sawyer and Spooner 1979) on enclosures:

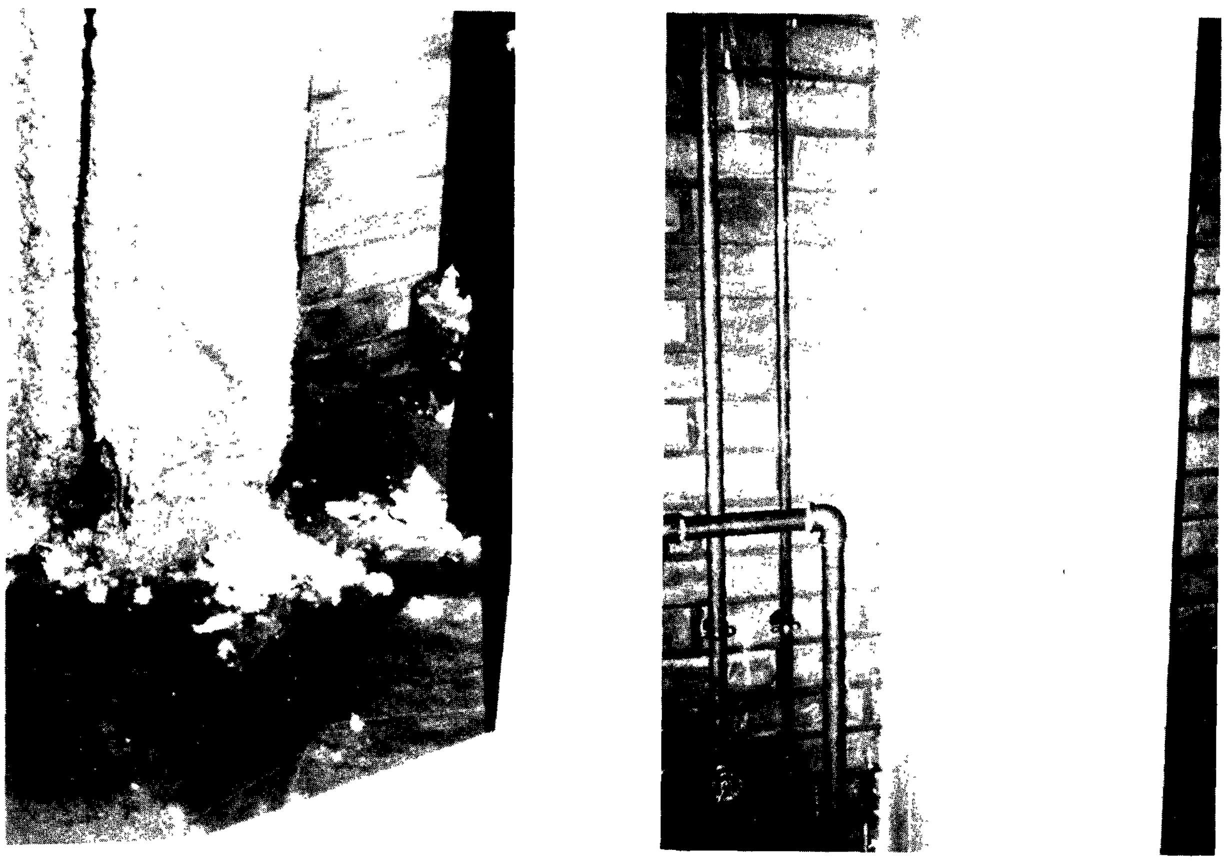
- As noted above, OSHA regulations and EPA recommendations for protecting workers and building occupants are not binding for enclosure activities. But using respirators and containment barriers is certainly a good idea. Installing an enclosure will probably mean drilling and anchoring into dry asbestos-covered surfaces. This releases dry asbestos fibers and could raise airborne asbestos concentrations to highly dangerous levels. Drills equipped with HEPA vacuum filters will reduce fiber release.
- Underlying structures must be able to support new walls and ceilings.
- New construction material should be impact-resistant and assembled to be airtight. Gypsum panels taped at the seams, tongue and groove boards, and boards with spline joints all qualify. Suspended ceilings with lay-in panels do not. Joints between walls and ceilings should be caulked.
- If lights are recessed into asbestos-containing material, they must be removed carefully to minimize the release of fibers. Lights should be reinstalled in or beneath the new ceiling.
- Plumbing lines and computer cables may have to be relocated.
- Building records must note the presence of asbestos behind the enclosure to prevent accidental fiber release during remodeling and building demolition. Cautionary signs placed on the enclosure may be a good idea.

When appropriate worker protection and worksite containment measures are employed, the initial cost of constructing enclosures is close to that of asbestos removal and disposal. Since sealing the substrate and replacing asbestos-containing material are not required, total project cost for enclosure initially may be somewhat lower. But the cost of periodic inspections and repair of enclosures for the life of the building, and of asbestos removal before demolition, may eliminate this cost saving in the long run.

---

*This cost range also reflects the experience of several Regional Asbestos Coordinators.

†No enclosure will be literally airtight. The building practices recommended here are designed to greatly reduce air movement across the enclosure boundary.



Before enclosure After enclosure

Figure 11. An asbestos enclosure project.

3.3.1.3 Encapsulation with Sealants

Encapsulation involves spraying asbestos-containing material with a sealant. Ideally, this activity helps bind together the asbestos fibers and other material components and offers some resistance to impact damage. As with enclosures, encapsulants are, at best, a temporary control measure. The asbestos-containing materials will still have to be removed before building demolition. In addition, the presence of encapsulants can make wetting and thus removing the material more difficult. Figure 12 shows an asbestos encapsulation project.

Basic information on selecting and applying sealants was given in Parts I (Chapter 8) and 2 (Chapter 3, Part II) of EPA's initial guidance (USEPA 1979, Sawyer and Spooner 1979). Encapsulation can be used on granular, cementitious material—commonly known as acoustical plaster. A sealant should penetrate the asbestos-containing material and adhere to the substrate (or form a tough skin over the material), withstand moderate impact, be flexible and flame retardant, resist deterioration over time, and be nontoxic. EPA recently sponsored an evaluation of over 100 sealants using five criteria: impact resistance, flame spread, smoke generation, toxic gas release during combustion, and adhesive/cohesive strength (USEPA 1981). The American Society of Testing and Materials (ASTM) also is developing laboratory testing criteria for sealants. Additional information on the EPA sealant study can be obtained from EPA's Office of Toxic Substances, Industry Assistance Office, (800) 334-8571.

Although the EPA study can help building owners choose a sealant, each sealant being considered should be tested on site. In this way, its effectiveness on the materials under consideration can be seen. Testing should be done over several days. The ASTM activity noted above will include criteria and procedures for field as well as laboratory tests. Material that is deteriorated or delaminated, or that shows extensive damage, should not be encapsulated. If delaminated, the additional weight will pull it down; if deteriorated, it may be blown off by application of sealant; if extensively damaged, it may be subject to repeated abuse and the sealant will not hold up. The condition of the sealant on previously encapsulated materials also should be inspected. Reapplication of sealant may be necessary.

Latex paint also has been used as a sealant. Its applicability is likewise limited to granular, cementitious materials. If latex paint is to be used, a brand with a high vehicle content (at least 60 percent by weight) and at least 25 percent (by weight) vehicle resin solids should be selected. For the purpose of encapsulating asbestos-containing material, paint should be applied considerably thicker than recommended for painting purposes. Experience suggests that coverage should be no more than 100 square feet per gallon.

Sealants should be applied with airless spray equipment. One recommended method is to apply a light (mist) coat, then a full coat applied at a 90 degree angle to the direction of the first. Latex paint can also be applied by roller following the application of the mist coat before it dries.

Encapsulation may be as costly as removal and disposal. This is largely due to the need for work area containment and worker protection measures during sealant application.* As with enclosure, no additional costs to replace asbestos-containing material are necessary. However, long-run costs are likely to be more than for removal due to (1) continuing inspection, (2) periodic reapplication of sealant, and (3) removal of asbestos-containing material before building demolition. (Encapsulation may make eventual removal more costly and hazardous since the material will probably need to be removed in dry form.)

---

*The use of respirators is recommended for the application of any sealant. Solvent-based (as compared to water-based) sealants may require the use of a supplied air (Type C) respirator due to hazards from the solvent.

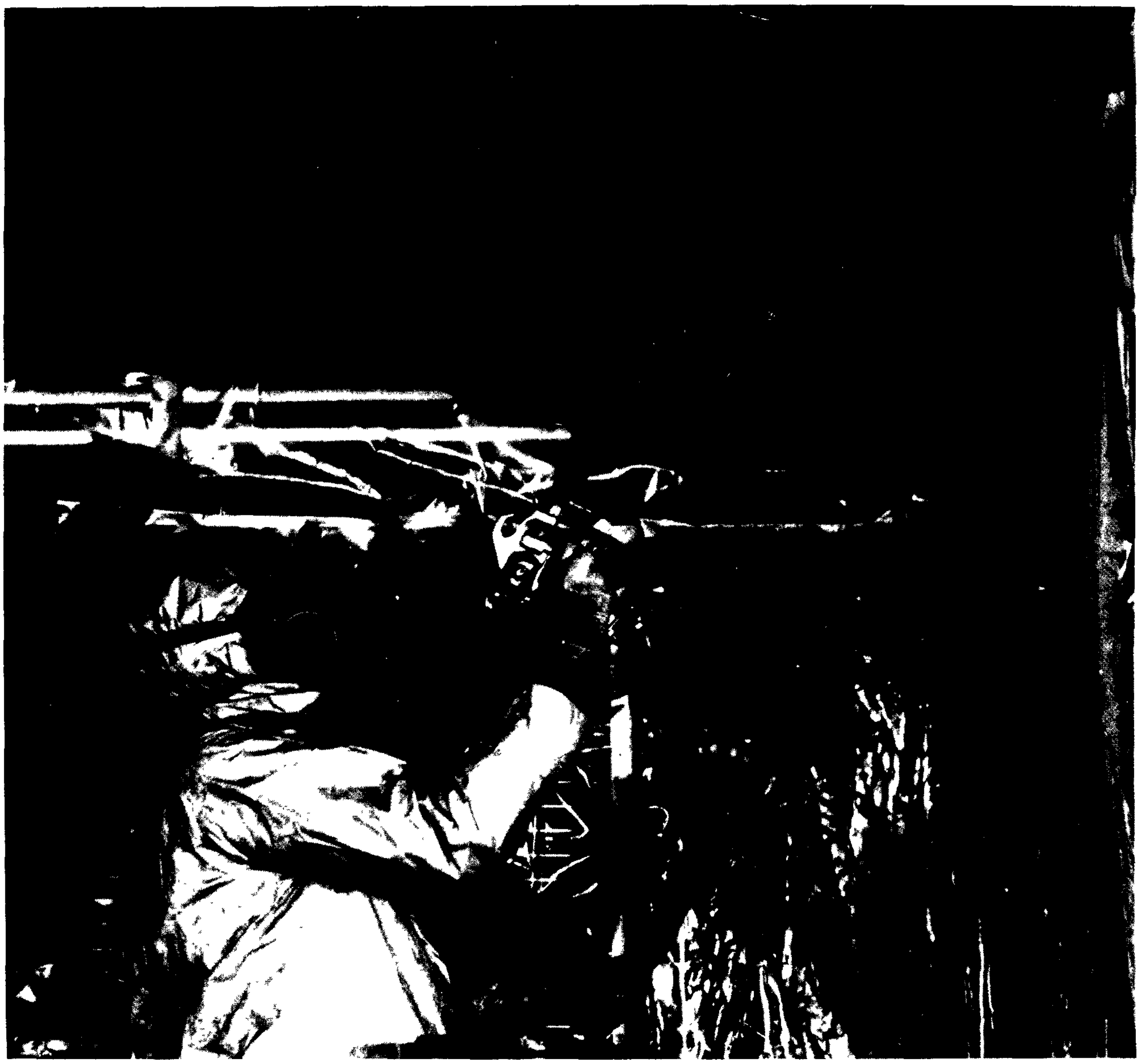


Figure 12. An asbestos encapsulation project.

Accurate, detailed records on the type of sealant used and the nature of the material and substrate encapsulated are critical. This information is needed to avoid unintentional release of fibers during remodeling or demolition.

3.3.1.4 Special Operations and Maintenance Procedures and Periodic Reassessment

An active program of building cleanup followed by proper maintenance and periodic reassessment of the need for other control measures seems to be appropriate where the asbestos-containing material is in good condition and has a low potential for disturbance or erosion. Other control measures will depend on the results of future reassessments. (In the past, this option has been called "deferred action.") It minimizes current costs while providing reasonable assurance of protection to building occupants.

Components of an initial cleanup program are the same as those of the interim control program described in the introduction to Section 3.3.1. Fibers are removed from carpets, floors, and all other horizontal surfaces. Building occupants and maintenance personnel are cautioned about damage to asbestos-containing materials.

All custodial and maintenance personnel should be instructed in special operations procedures. They should be cautioned about removing suspended ceiling panels, installing lighting or plumbing fixtures, repairing air handling systems, or, in general, engaging in any activity that might damage asbestos-containing material or resuspend fibers. Building occupants should be warned not to disturb the material by such acts as hanging plants from asbestos-covered ceilings and damaging walls with furniture.

Periodic reassessments should focus on the condition of the asbestos-containing materials, changes in building use, and changes in occupants' activity patterns. If reassessment suggests that fiber release has occurred or is likely, then other corrective actions should be formally evaluated.

3.3.2 Control Measures for Pipe and Boiler Insulation

Controlling asbestos-containing materials used to insulate pipes and boilers is different but not necessarily more difficult than controlling asbestos-sprayed or -troweled surfaces. Asbestos-containing pipe insulation takes many forms, including chalky mixtures of magnesia and asbestos, preformed fibrous asbestos wrapping, asbestos fiber felt, corrugated paper, and insulating cement. In most cases, the insulating material is covered with a protective jacket (lagging) made of cloth, tape, paper, metal, or cement. (Figure 13 is a photograph of deteriorated and damaged pipe insulation.) Boiler insulation may consist of thermal bricks (refractory) or asbestos insulating blankets, but is usually covered with a finishing cement. Occasionally, asbestos millboard is used as outside lagging on removable insulating covers for stiffness. Lagging on pipes and boilers prevents spontaneous fiber release and helps protect against disturbance. Damage from physical impact or water exfiltration is relatively easy to observe and repair. On the other hand, not all parts of steam or hot water distribution networks are readily accessible, and the high temperatures (if the steam cannot be shut off) can make abatement an arduous task.

Where damage to pipe covering or boiler lagging is limited, the most straightforward approach to abatement is repair. Duct tape can be used to seal open joints, and plastering with nonasbestos material can restore large damaged areas or areas around valves and flanges to their original condition. Where large portions of material must be removed, however, one should use the same protective measures taken in the removal of materials sprayed or

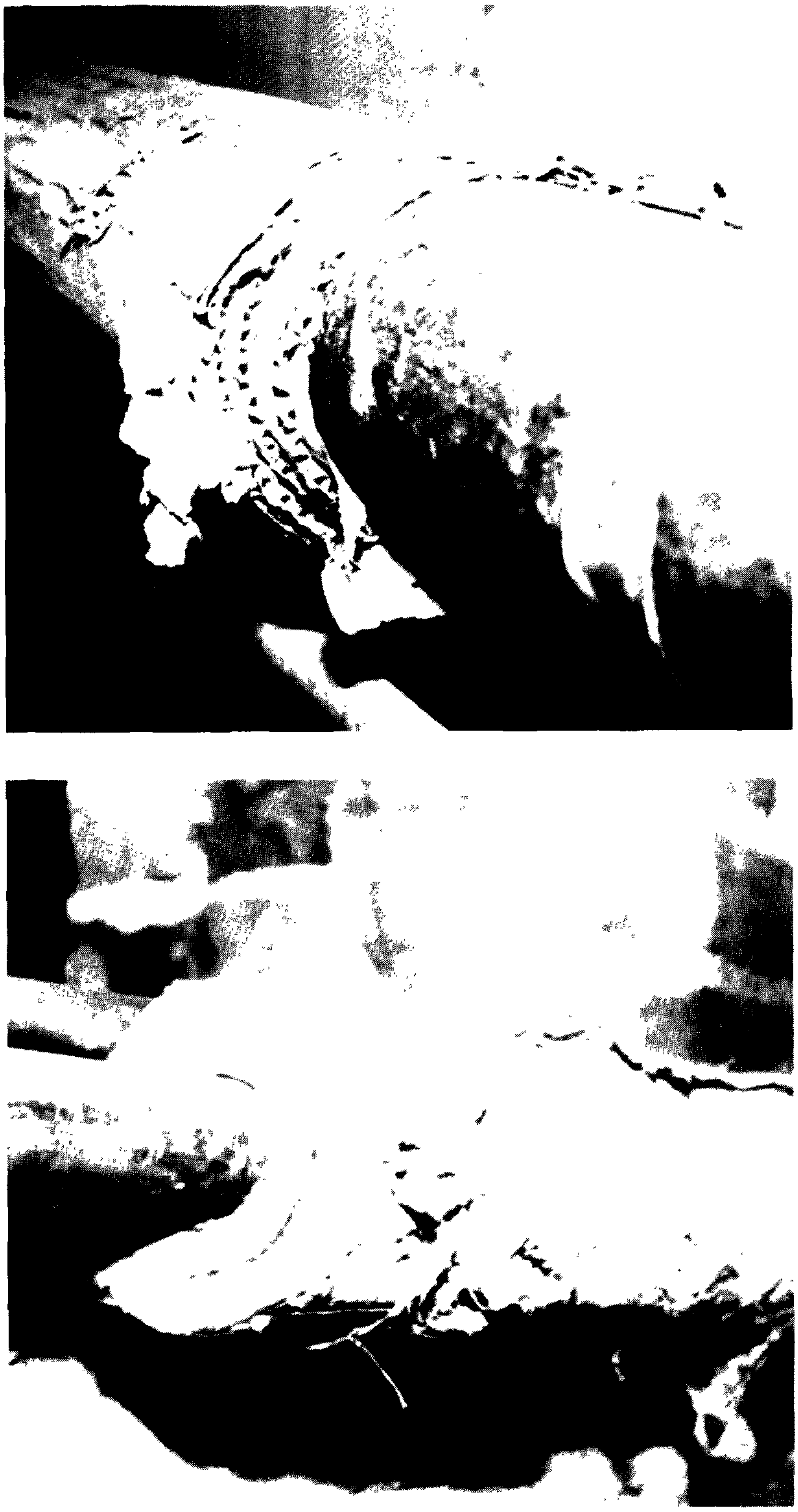


Figure 13. Pipe insulation in damaged and deteriorated condition

troweled onto surfaces. That is, containment barriers should be erected and the full range of worker protection devices must be employed. Containment bags with sealed holes for hand access are alternatives to full room or full work area containment. As shown in Figure 14, these bags are positioned around the pipe insulation to be removed and sealed to the pipe with tape. Armholes and an inside pouch for tools let the worker remove insulation without exposure to asbestos fibers. A sealed side port also can be constructed to allow access for wetting the asbestos and evacuating the bag with a HEPA-filtered vacuum. These bags are available commercially.

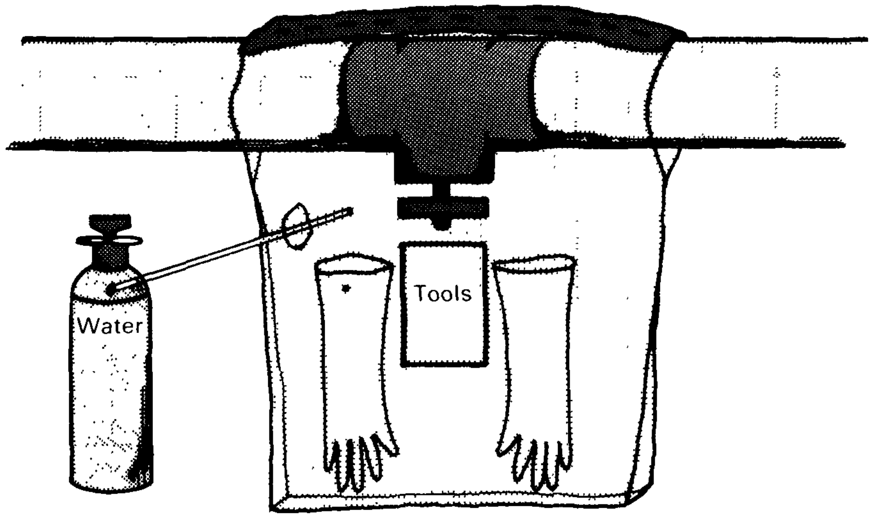


Figure 14. Custom containment bags for repairing or removing pipe insulation.

To remove individual pipe sections or an entire network, small sections, about an inch wide, of insulation should be removed. The pipe then can be cut into manageable lengths with a torch. At a minimum, exposed ends of the insulating material should be sealed with plastic and tape. If the remaining insulation is not in good condition the entire pipe should be wrapped in 6 mil plastic. More information on pipe and pipe insulation removal will be provided in a forthcoming technical bulletin.

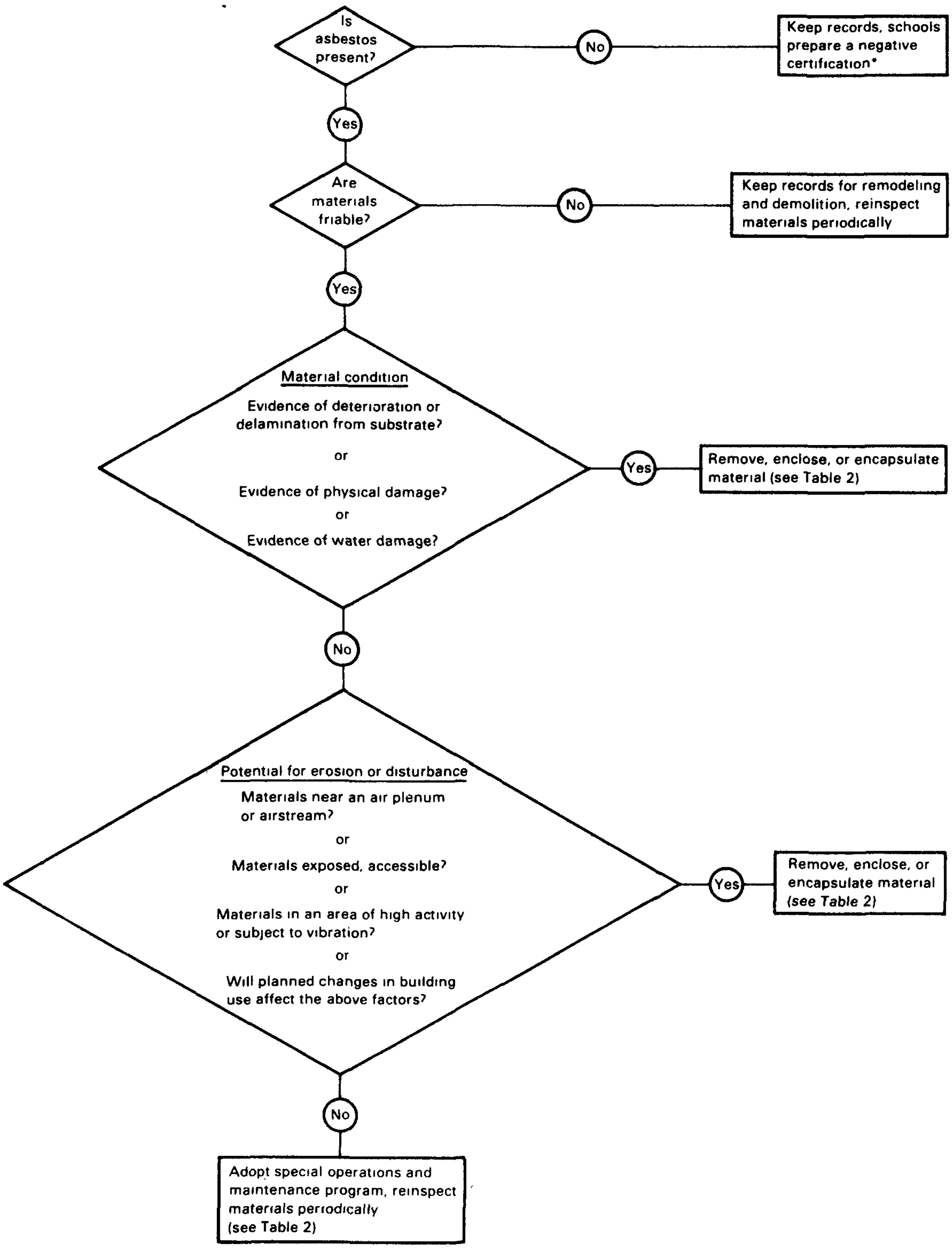
Disposal of insulation and lagging material must follow the same EPA procedures discussed earlier and in Chapter 9 and Appendix A, Part I of the initial EPA guidance (USEPA 1979) for asbestos waste.

3.4 The Decision-Making Process

Selecting a course of action for controlling asbestos-containing materials is a complicated task. A large amount of complex information can be generated during the asbestos assessment process. Evaluating and applying this information to the control alternatives may be slow and difficult. Moreover, each building owner faces special circumstances involving building use and conditions. Attempts to develop a set of definitive decision rules with broad applicability are therefore of little value. However, using a systematic process for organizing and interpreting relevant information has proven to be of considerable value. This section outlines the key steps in such a process.

Figure 15 presents a sequence of questions which can be used to organize information and guide decision-makers. Using the information available at each stage of an asbestos

Figure 15. A guide to selecting a course of action.



*A statement certifying that friable asbestos-containing materials are not present.

investigation, the decision-maker is guided toward groups of appropriate responses. In essence, if friable asbestos-containing materials are present and determined to be (1) in bad condition, or (2) subject to erosion or disturbance, then the material should be removed, enclosed, or encapsulated. Only if the material is in good condition and unlikely to be disturbed or eroded should a special operations, maintenance, and periodic reinspection program be selected as the corrective action. If the asbestos-containing materials are nonfriable, no corrective action is needed. Instead, the nature and location of these materials should be documented and their condition should be reassessed periodically.

The questions in Figure 15 are based on the assessment factors discussed in Section 3.2.2.2. The evaluation of factors that indicate material condition and the potential for erosion or disturbance is subjective. For example, determining if water damage is evident or the material is accessible requires judgment by trained and/or experienced evaluators. The descriptions of individual assessment factors in Appendix D are an excellent starting point for training evaluators.

Once Figure 15 has been used to choose between a special operations and maintenance program or the direct treatment of asbestos-containing materials, the decision-maker is directed to Table 2, which summarizes asbestos control alternatives. Advantages and disadvantages of each control measure are presented together with information on appropriate and inappropriate applications.

Several items in Table 2 are particularly important:

- Removal has the widest applicability of all control alternatives. It also is the only truly permanent solution, since no building containing asbestos can be demolished without first removing the asbestos. It is the only control measure which can guarantee elimination of asbestos exposure.
- Enclosure and encapsulation must be followed with a special operations program and with periodic reinspection of the enclosed or encapsulated materials.
- Removal, enclosure, and encapsulation should be undertaken only after construction of sealed containment barriers.
- Proper worker protection is mandated by OSHA for removal operations, and is needed for enclosure and encapsulation activities as well.

Table 2 shows that the initial cost of removal may be higher than for the other control measures. However, several building owners have found that long-term costs of removal may be lower when considering the need for special operations practices, periodic reinspection, and repairs if the material is enclosed or encapsulated. The cost of eventually removing enclosed or encapsulated materials prior to demolition must also be considered.

Table 2. Comparison of Asbestos Control Alternatives

Method	Advantages	Disadvantages	Appropriate applications	Inappropriate applications	General comments
Removal	Eliminates asbestos source Eliminates need for special operations and maintenance program	Replacement with substitute material may be necessary Porous surfaces also may require encapsulation Improper removal may raise fiber levels	Always	Never	Containment barriers needed Worker protection required Wet removal is required for all types of asbestos, (amosite will not adsorb water or water with traditional wetting agents) Disposal may be a problem in some areas Unusual circumstances, complex surfaces, and the presence of utilities may require special removal techniques
Enclosure	Reduces exposure in the area outside the enclosure Initial costs may be lower than removal unless utilities need relocating or major changes Usually does not require replacement of material	Asbestos source remains and must be removed eventually Fiber release continues behind enclosure Special operations program required to control access to enclosure for maintenance and renovation Periodic reinspection required to check for damage Repair of damaged enclosure necessary Fibers released in dry form during construction of enclosure Long-term costs could be higher than removal	When materials need to be isolated from building occupants (e g , exposed pipe) Disturbance or entry into enclosed area unlikely	Damaged or deteriorating materials causing rapid fiber release Water damage evident Damage or entry into enclosure likely Ceiling to be enclosed is low	Containment barriers needed Use of tools with HEPA-filtered vacuum attachments advisable Worker protection needed

Table 2. (continued)

Method	Advantages	Disadvantages	Appropriate applications	Inappropriate applications	General comments
Encapsulation	Reduces asbestos fiber release from material Initial costs may be lower than removal Does not require replacement of material	Asbestos source remains and must be removed later If material is not in good condition, sealant may cause material to delaminate	Material still retains bonding integrity Damage to material not likely Material not highly accessible	Material does not adhere well to substrate Material is deteriorating or damaged, or damage is likely Water damage is evident	Containment barriers needed Worker protection needed Airless sprayers should be used
		Periodic reinspection required to check for damage or deterioration Repair of damaged or deteriorating encapsulated surface required Encapsulated surface is difficult to remove and may require dry techniques for eventual removal Long-term costs may be higher than removal	Material granular, cementitious	Material is fibrous, fluffy	Damaged pipe insulation may be taped but not sprayed Previously encapsulated materials may have to be re-encapsulated
Special operations and maintenance program plus periodic reinspection	Lowest initial cost of any alternative	Asbestos source remains Special operations program required to prevent damage of material during maintenance or renovation Periodic reinspection required to assess material condition and potential for erosion or disturbance	As a temporary measure until another alternative is selected Material in good condition and has low potential for erosion or disturbance Material is nonfriable	Material not in good condition or has high potential for erosion or disturbance	Special building cleaning practices are essential

CHAPTER 4 — DETERMINING ABATEMENT COMPLETION

Determining successful performance on individual abatement projects is one of the most difficult problems faced by the asbestos program manager. Insistence on specific work practices and continuing surveillance during abatement are essential to a successful abatement project. Releasing the contractor from a project depends on specific criteria being met. This chapter discusses two types of criteria—visual inspection of the worksite and air monitoring after completion of the project. Major points in this chapter are summarized below.

Visual Inspection: Regardless of other abatement performance measures considered, *a visual inspection should always be made. The nature of visual inspection* will vary with the type of abatement activity. The inspection should detect incomplete work, damage caused by the abatement activity, and inadequate cleanup of the worksite.

Air Monitoring: Measurement of total airborne fibers by phase contrast microscopy should supplement visual inspection to confirm adequate job cleanup. Such measurement can determine whether elevated levels of airborne fibers generated *during the abatement project have been sufficiently reduced.*

4.1 Visual Inspection

Every abatement contract should require a thorough visual inspection of the worksite after project completion. The inspection should be conducted before the containment barriers have been taken down but after the plastic sheets have been cleaned with damp mops and cloths. Only after the worksite has passed inspection should the contractor be released. The inspector (program manager or technical expert) first should check on the completeness of the job. If asbestos-containing material has been removed, all substrate surfaces should be inspected for adhering material. Special attention should be given to pipes, beams, and irregular surfaces that may have corners and areas that are difficult to reach. Enclosures should be checked for tight construction (for example, no stray drill holes or openings at enclosure corners). Encapsulated surfaces should be inspected for thin application of sealant. Surfaces behind obstructions (for example, pipes or ducts) are suspect areas and should be checked.

Visual inspection also should include a check for damage. Wet removal with inadequate floor protection may cause warping of wooden floors. Also, disassembling the containment barriers sometimes causes wall or ceiling paint to peel.

A third function of the visual inspection is to ensure that the worksite has been adequately cleaned. Any activity which disturbs asbestos-containing material will release fibers. Therefore, worksite cleanup after removal, enclosure, or encapsulation activities is critical. All surfaces should be checked for dust and debris, especially overhead surfaces such as tops of suspended light fixtures. Use a damp cloth to collect dust from these surfaces and then inspect the cloth for visible evidence of dust. This is a convenient way to establish that the "no dust" requirement has been met.

4.2 Air Monitoring

Visual inspection can be used to check for fiber accumulation (as well as general debris) on floors and other surfaces. It cannot measure the level of residual asbestos fibers in the air. Air monitoring thus can be used along with visual inspection to be sure the worksite is clean. Monitoring should be conducted only after the worksite has passed a thorough visual inspection.

As discussed in Chapter 3 (Section 3.3.2), the direct measurement of airborne asbestos fibers requires the use of electron microscopy (EM) and is both technically complex and expensive. However, the NIOSH recommended air monitoring method based on phase contrast microscopy (PCM) is a practical alternative to EM for this application. The detection limit of PCM can be used to establish that levels of total (asbestos and nonasbestos) fibers generated during an abatement action have been sufficiently reduced. Using the sampling specifications described below coupled with PCM measurement provides a practical air monitoring test to complement visual inspection as criteria for releasing abatement contractors.

The following sampling and analysis specifications are suggested for air monitoring after project completion and before containment barriers are dismantled:

- Sampling should begin after all surfaces at the worksite have dried but preferably within 48 hours after abatement work is finished.
- A total of approximately 1,000 liters or more of air should be sampled at a rate of no more than 2 liters per minute. (Thus, an 8-hour sampling period would produce a sample volume of 960 liters.)
- A minimum of three monitors per worksite and at least one per room should be used.

For a sample volume of approximately 1,000 liters of air, the lower detection limit for phase contrast microscopy is about 0.03 fibers per cubic centimeter.* It must be noted that the lower detection limit decreases as the volume of air sampled increases. Therefore, if the lower detection limit is used as a standard for releasing the contractor, the standard can be made more stringent (lower than 0.03 fibers per cubic centimeter) by increasing the volume of air sampled.

Table 3 shows calculated detection limits for various sampling volumes. As shown, a sampling volume of almost 3,000 liters will decrease the detection limit of PCM to 0.01 fibers per cubic centimeter. This table also can serve as a guide for determining whether levels of airborne fibers reported by air monitoring contractors are reliable for sampling volumes less than 1,000 liters, even though such low volumes are not recommended. More information on detection limits can be found in Appendix G.

Table 3. Total Airborne Fiber Detection Limits and Associatied Sampling Volumes (for the NIOSH P&CAM 239 Method)

Sampling time @ 2 liters per minute (hours)		Volume collected (liters)	Detection limit[a] (fibers per cubic centimeter)
2	Not recommended	240	0 119
6		720	0.041
8		960	0.030
24		2,880	0.010

[a]Assumes a microscopic field area of 0 003 square millimeters Some microscopes have field areas as large as 0.006 square millimeters, which would decrease the detection limits shown by half See Appendix G for details.

*This determination is based on a minimum detection limit of 10 fibers per 100 microscopic fields for PCM reported in Leidel, et al 1979. See Appendix G for additional information on calculating detection limits.

Regardless of what air level is selected as the standard for releasing abatement contractors, it should be applied at each monitor. If any monitor shows a total fiber level higher than that allowed, the worksite should be recleaned with a HEPA-filtered vacuum cleaner and/or damp cloths and mops. A new set of air samples for the entire worksite should be collected and analyzed.

It is important to acknowledge that PCM measurements of airborne fibers at the worksite following project completion serve only to indicate that the elevated levels of total fibers observed during the abatement action have been reduced. The PCM measurements cannot be used to document the absolute levels of asbestos in the building.

References

Constant PC Jr, Bergman FJ, Atkinson GR, Rose DR, Watts DL, Logue EE, Hartwell TD, Price BP, Ogden JS. 1982. *Airborne Asbestos Levels in Schools.* Draft report. Washington, DC: Office of Pesticides and Toxic Substances. U.S. Environmental Protection Agency. Contracts 68-01-5915 and 68-01-5848.

Lory EE. 1980. *Asbestos Friable Insulation Material (FIM) Risk Evaluation Procedure for Navy Facilities.* Port Hueneme, CA: Civil Engineering Laboratory, U.S. Navy.

Lucas D, Hartwell T, Rao AV. 1980a. *Asbestos-Containing Materials in School Buildings: Guidance for Asbestos Analytical Programs.* Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency.

Lucas D, Hartwell T, Rao AV. 1980b. *Asbestos-Containing Materials in School Buildings: Guidance for Asbestos Analytical Programs, Statistical Background Document.* Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency.

Nicholson WJ, Rohl AM, Ferrand EF. 1971. "Asbestos Air Pollution in New York City." In: Proceedings of Clean Air Congress. England HM, Barry WT, eds. New York: Academic.

Nicholson WJ, Rohl AM, Weisman I. 1975. *Asbestos Contamination of the Air in Public Buildings.* Washington, DC: U.S. Environmental Protection Agency.

Pinchin DJ. 1982 (June). *Asbestos in Buildings.* Mississauga, Ontario, Canada: Ontario Research Foundation.

Samudra AV, Horwood CF, Stockham JD. 1977 (revised June 1978). *Electron Microscope Measurement of Airborne Asbestos Concentrations.* Research Triangle Park, NC: Office of Research and Development, U.S. Environmental Protection Agency.

Sawyer RN, Spooner DM. 1979b. *Asbestos-Containing Materials in School Buildings: A Guidance Document, Part 2.* Washington, DC. Office of Toxic Substances, U.S. Environmental Protection Agency.

Sebastien P, Bellon-Galland MA, Dufour G, Petit G, Goudichet A. 1982. *Assessment of Asbestos Exposure in Buildings with Sprayed Materials Using Both the Algorithm Method and the ATEM Measurement Method.* Paris, France: Direction des Affaires Sanitaires et Sociales de Paris.

USEPA. 1979. U.S. Environmental Protection Agency. *Asbestos-Containing Materials in School Buildings: A Guidance Document, Part 1.* Washington, DC: Office of Toxic Substances, USEPA.

USEPA. 1980. U.S. Environmental Protection Agency. *Asbestos-Containing Materials in Schools, Economic Impact Analysis of Identification and Notification Proposed Rule, Sec. 6, TSCA.* Washington, DC: Office of Toxic Substances, USEPA. EPA-560/12-80-004.

USEPA. 1981. U.S. Environmental Protection Agency. *Evaluation of Encapsulants for Sprayed-On Asbestos-Containing Materials in Buildings.* Summary. Cincinnati, OH: Office of Research and Development, USEPA.

USEPA. 1982. U.S. Environmental Protection Agency. *Support Document for Final Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure.* Washington, DC: Office of Toxic Substances, USEPA.

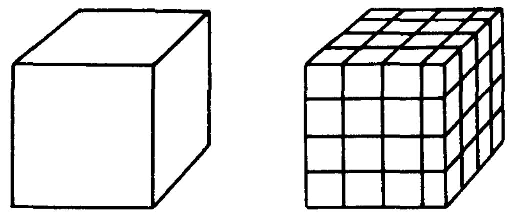
Versar Inc. 1980. *Exposures to Commercial Asbestos, Sec. 3: Comparability of Asbestos Data.* Preliminary draft report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-01-5791.

Appendix A. Common Units Used in Measuring Airborne Asbestos Concentrations

Length

1 meter (m)	= 39.37 inches or 3.28 feet
100 centimeters (cm)	= 1 meter
1,000,000 micrometers (μm)	= 1 meter

Volume



1 cubic m (m^3) = 35.3 cubic feet

1,000,000 cm^3 = 1 m^3

1,000 cm^3 = 1 liter

Weight (mass)

454 grams (g) = 1 pound

1,000,000,000 nanograms (ng) = 1 gram

Concentration (mass contained in a stated volume)

2 fibers per cm^3 (the current 8-hour OSHA industrial standard) means that 2 fibers are present in each cm^3 of air. Since there are 1,000,000 cm^3 in 1 m^3, there would be 2,000,000 fibers in a m^3.

If each fiber is chrysotile asbestos (density of 0.0026 ng/μm^3) and is just long and thick enough to be detected by the NIOSH procedure for determining compliance with the OSHA standard (5 μm in length and 0.3 μm in diameter), it would weight 0.0092 ng:

Mass = $\pi/4$ (diameter)^2 (length) (density)

$$\pi/4\ (0.3\ \mu m)^2\ (5\ \mu m)\ (0.0026\ ng/\mu m^3) = 0.0092\ ng$$

A total of 2,000,000 of these fibers would weigh about 1,800 ng.

Since the fibers in the above example are the smallest (shortest and thinnest) counted by the NIOSH procedure, fibers actually measured using this protocol are typically larger and thus weigh more. Comparison of fibers in this example with those actually measured is further complicated since nonasbestos as well as asbestos fibers are counted by the NIOSH protocol. As noted in the footnote to Figure 1, comparisons of total fibers counted with the mass of asbestos measured in air samples indicate that, on an average, about 30 fibers counted by the NIOSH procedures equal one nanogram of asbestos. This relationship applies to samples collected during the spray application of asbestos insulation. For these samples, each fiber counted weighs an average of 0.033 ng, or about 37 times more than those in the example, and 2,000,000 of them would weigh about 67,000 ng.

Appendix B. Addresses of EPA Regional Asbestos Coordinators

EPA Region I
Asbestos Coordinator
Air and Hazardous Material Division
JFK Federal Building
Boston, Massachusetts 02202
(617) 223-0585

EPA Region II
Asbestos Coordinator
Woodbridge Avenue
Edison, New Jersey 08837
(201) 321-6668

EPA Region III
Asbestos Coordinator
Curtis Building
6th and Walnut Street
Philadelphia, Pennsylvania 19106
(215) 597-9859

EPA Region IV
Asbestos Coordinator
345 Cortland Street
Atlanta, Georgia 30365
(404) 881-3864

EPA Region V
Asbestos Coordinator
230 S. Dearborne Street
Chicago, Illinois 60604
(312) 886-6003

EPA Region VI
Asbestos Coordinator
First International Building
1219 Elm Street
Dallas, Texas 75270
(214) 767-2734

EPA Region VII
Asbestos Coordinator
324 E. 11th Street
Room 1411
Kansas City, Missouri 64106
(816) 374-6538

EPA Region VIII
Asbestos Coordinator
1860 Lincoln Street
Denver, Colorado 80295
(303) 837-3926

EPA Region IX
Asbestos Coordinator
215 Fremont Street
San Francisco, California 94105
(415) 974-8123

EPA Region X
Asbestos Coordinator
1200 6th Avenue
Seattle, Washington 98101
(206) 442-2632

Appendix C. Asbestos-Containing Materials Found in Buildings*

Asbestos-containing construction materials and products can be divided into two categories:

- Category I — Friable materials; and
- Category II — Nonfriable matrix-bonded composite products, and textile products.

Friable materials are those which can be crumbled, pulverized, or reduced to powder in the hand—readily releasing fibers with minimal mechanical disturbance. Most insulating materials sprayed or troweled onto surfaces are friable.

Nonfriable, matrix-bonded composite products are prepared by mixing fibers with various bonding agents (e.g., starch, glue, plastics, cements, asphalt). The degree of asbestos fiber immobilization and the degree of release vary according to use, environmental conditions, and physical damage. Friable materials covered with a hard wrap or coating, such as pipe insulation, are considered nonfriable unless damage to the wrap exposes the friable material.

In asbestos textile products, raw asbestos fibers and fibers of numerous other materials, both of organic and inorganic origin, are worked into rovings, yarns and cords and can be woven, braided, or knitted. Usually, binding agents are not used in these products but many are coated.

Each of the two major categories can be subdivided into several more specific groups of products. Table C-1 contains information on the percent asbestos, generic name, dates of use, and binder/sizing of the subdivision.

*The information in this Appendix is taken, with modification, from: Lory EE, Coin DC. February 1981. *Management Procedure for Assessment of Friable Asbestos Insulating Material.* Port Hueneme, CA: Civil Engineering Laboratory Naval Construction Battalion Center. The U.S. Navy prohibits the use of asbestos-containing materials when acceptable nonasbestos substitutes have been identified.

Table C-1. Various Types of Friable and Nonfriable Materials and Products (as of 1977)

Subdivision	Generic name	Asbestos (%)	Dates of use	Binder/sizing
Friable insulation material	spray-applied insulating	1-95	1935-1970	sodium silicate, portland cement, organic binders
Preformed thermal insulating products	batts, blocks, and pipe covering			
	85% magnesia	15	1926-1949	magnesium carbonate
	calcium silicate	6-8	1949-1971	calcium silicate
Textiles	cloth[a]			
	blankets (fire)[a]	100	1910-present	none
	felts	90-95	1920-present	cotton/wool
	blue stripe	80	1920-present	cotton
	red stripe	90	1920-present	cotton
	green stripe	95	1920-present	cotton
	sheets	50-95	1920-present	cotton/wool
	cord/rope/yarn[a]	80-100	1920-present	cotton/wool
	tubing	80-85	1920-present	cotton/wool
	tape/strip	90	1920-present	cotton/wool
	curtains[a]			
	(theatre, welding)	60-65	1945-present	cotton
Cementitious concrete-like products	extrusion panels	8	1965-1977	portland cement
	corrugated	20-45	1930-present	portland cement
	flat	40-50	1930-present	portland cement
	flexible	30-50	1930-present	portland cement
	flexible perforated	30-50	1930-present	portland cement
	laminated (outer surface)	35-50	1930-present	portland cement
	roof tiles	20-30	1930-present	portland cement
	clapboard and shingles			
	clapboard	12-15	1944-1945	portland cement
	siding shingles	12-14	unknown-present	portland cement
	roofing shingles	20-32	unknown-present	protland cement
	pipe	20-15	1935-present	portland cement
Paper products	corrugated			
	high temperature	90	1935-present	sodium silicate
	moderate temperature	35-70	1910-present	starch
	indented	98	1935-present	cotton and organic binder
	millboard	80-85	1925-present	starch, lime, clay
Roofing felts	smooth surface	10-15	1910-present	asphalt
	mineral surface	10-15	1910-present	asphalt
	shingles	1	1971-1974	asphalt
	pipeline	10	1920-present	asphalt

Table C-1. (continued)

Subdivision	Generic name	Asbestos (%)	Dates of use	Binder/sizing
Asbestos-containing compounds	caulking putties	30	1930-present	linseed oil
	adhesive (cold applied)	5-25	1945-present	asphalt
	joint compound		1945-1975	asphalt
	roofing asphalt	5	unknown-present	asphalt
	mastics	5-25	1920-present	asphalt
	asphalt tile cement	13-25	1959-present	asphalt
	roof putty	10-25	unknown-present	asphalt
	plaster/stucco	2-10	unknown-present	portland cement
	spackles	3-5	1930-1975	starch, casein, synthetic resins
	sealants fire/water	50-55	1935-present	caster oil or polyisobutylene
	cement, insulation	20-100	1900-1973	clay
	cement, finishing	55	1920-1973	clay
	cement, magnesia	15	1926-1950	magnesium carbonate
Asbestos ebony products		50	1930-present	portland cement
Flooring tile and Sheet Goods	vinyl/asbestos tile	21	1950-present	poly(vinyl)chloride
	asphalt/asbestos tile	26-33	1920-present	asphalt
	sheet goods/resilient	30	1950-present	dry oils
Wallcovering	vinyl wallpaper	6-8	unknown-present	—
Paints and coatings	roof coating	4-7	1900-present	asphalt
	air tight	15	1940-present	asphalt

[a]Laboratory aprons, gloves, cord, rope, fire blankets, and curtains may be common in schools.

Appendix D. Definition and Description of Factors for Assessing the Need for Corrective Action*

D.1 Condition of the Asbestos-Containing Material

D.1.1 Factors 1 and 2: Deterioration or Delamination and Physical Damage

An assessment of the condition should evaluate: the quality of the installation, the adhesion of the friable material to the underlying substrate, deterioration, and damage from vandalism or any other cause. Evidence of debris on horizontal surfaces, hanging material, dislodged chunks, scrapings, indentations, or cracking are indicators of poor material condition.

Accidental or deliberate physical contact with the friable material can result in damage. Inspectors should look for any evidence that the asbestos-containing material has been disturbed: finger marks in the material, graffiti, pieces dislodged or missing, scrape marks from movable equipment or furniture, or accumulation of the friable material on floors, shelves, or other horizontal surfaces.

Asbestos-containing material may deteriorate as a result of either the quality of the installation or environmental factors which affect the cohesive strength of the asbestos-containing material or the strength of the adhesion to the substrate. Deterioration can result in the accumulation of dust on the surface of the asbestos-containing material, delamination of the material (i.e., separating into layers), or an adhesive failure of the material where it pulls away from the substrate and either hangs loosely or falls to the floor and exposes the substrate. Inspectors should touch the asbestos-containing material and determine if dust is released when the material is lightly brushed or rubbed.

If the coated surface "gives" when slight hand pressure is applied or the material moves up and down with light pushing, the asbestos-containing material is no longer tightly bonded to its substrate.

D.1.2 Factor 3: Water Damage

Water damage is usually caused by roof leaks, particularly in buildings with flat roofs or a concrete slab and steel beam construction. Skylights can also be significant sources of leaks. Water damage can also result from plumbing leaks and water or high humidity in the vicinity of pools, locker rooms, and lavatories.

Water can dislodge, delaminate, or disturb friable asbestos-containing materials that are otherwise in good condition and can increase the potential for fiber release by dissolving and washing out the binders in the material. Materials which were not considered friable may become friable after water has dissolved and leached out the binders. Water can also act as a slurry to carry fibers to other areas where evaporation will leave a collection of fibers that can become suspended in the air.

Inspect the area for visible signs of water damage, such as discoloration of or stains on the asbestos-containing material; stains on adjacent walls or floors; buckling of the walls or

*The information in this Appendix is taken, with modification, from: Brandner, W. October 1982. *Asbestos Exposure Assessment in Buildings Inspection Manual.* Kansas City, MO: U.S. Environmental Protection Agency, Region VII.

floors; or areas where pieces of the asbestos-containing material have separated into layers or fallen down, thereby exposing the substrate.

Close inspection is required. In many areas, staining may occur only in a limited area while water damage causing delamination may have occurred in a much larger area. In addition, the water damage may have occurred since the original inspection for friable material, causing new areas to become friable and require a reinspection.

Delamination is particularly a problem in areas where the substrate is a very smooth concrete slab. Check to see if the material "gives" when pressure is applied from underneath.

D.2 Potential for Disturbance or Erosion

D.2.1 Factor 4: Air Plenum or Direct Airstream

An air plenum exists when the return (or, in rare cases, conditioned) air leaves a room or hall through vents in a suspended ceiling and travels at low speed and pressure through the space between the actual ceiling and the suspended ceiling or ducts. The moving air may erode any asbestos-containing material in the plenum. In evaluating whether an air plenum or direct airstream is present, the inspector must look for evidence of ducts or cavities used to convey air to and from heating or cooling equipment or the presence of air vents or outlets which blow air directly onto friable material.

A typical construction technique is to use the space between a suspended ceiling and the actual ceiling as a return air plenum. In many cases, the tiles in the suspended ceiling must be lifted to check if this is the case. Inspection of the air handling or HVAC equipment rooms may also provide evidence (such as accumulated fibers) of the presence of this material in the plenums.

Special attention should be paid to whether frequent activities (such as maintenance) disturb the material in the plenum. It is also important to check for evidence that the material is being released or eroded (i.e., has it deteriorated or been damaged so that the material is free to circulate in the airstream?).

D.2.2 Factor 5: Exposure, Accessibility, and Activity

These three considerations are highly interrelated and have been combined into a single factor. In general, for a site to show a high potential for disturbance, it must be exposed (visible) and accessible, and be located near movement corridors or subject to vibration.

The amount of asbestos-containing material exposed to the area occupied by people will contribute to the likelihood that the material may be disturbed and determines whether the fibers can freely move through the area. An asbestos-containing material is considered exposed if it can be seen. For a material not to be exposed, a physical barrier must be complete, undamaged, and unlikely to be removed or dislodged. An asbestos-containing material should be considered exposed if it is visible, regardless of the height of the material.

If the asbestos-containing material is located behind a suspended ceiling with movable tiles, a close inspection must be made of the condition of the suspended ceiling; the likelihood and frequency of access into the suspended ceiling, and whether the suspended ceiling forms a complete barrier or is only partially concealing the material.

Asbestos-containing material above a suspended ceiling is considered exposed if the space above the suspended ceiling is an air plenum. Suspended ceilings with numerous louvers, grids, or other open spaces should be considered exposed.

If friable asbestos-containing material can be reached by building users or maintenance people, either directly or by impact from objects used in the area, it is accessible and subject to accidental or intentional contact and damage. Material which is accessible is likely to be disturbed in the future.

Height above the floor is one measure of accessibility. However, objects have been observed embedded in ceilings 25 feet or more high. Nearness of the friable asbestos-containing material to heating, ventilation, lighting and plumbing systems requiring maintenance or repair may increase the material's accessibility.

In addition, the activities and behavior of persons using the building should be included in the assessment of whether the material is accessible. For example, persons involved in athletic activities may accidentally damage the material on the walls and ceilings of gymnasiums with balls or athletic equipment. To become fully aware of occupants' use of the building, the *inspector should consult with building staff or personnel.*

When assessing activity levels, consider not only the movement caused by the activities of people but also movement from other sources such as high vibration from mechanical equipment, highways, and airplanes. Another source of vibration is sound, such as music and noise, which sets airwaves in motion at certain frequencies. As these sound waves impact on asbestos-containing material, they may vibrate the material and contribute to fiber release. Therefore, more fibers may be released in a music practice room or auditorium than in the rest of the building.

The amount of activity of the occupants can best be described by identifying the purpose of the area as well as estimating the number of persons who enter the area on a typical day.

D.2.3 Factor 6: Change in Building Use

A planned change in the use of the building from, for example, a junior to a senior high school may imply significant changes in the potential for erosion or disturbance. Of particular note is the increased potential for damage from balls to previously inaccessible ceilings in gymnasiums. The addition of machinery (such as dust collectors in wood or metal shops) to a school or office building may introduce vibrations which, again, may be a future cause of concern. The inspector should exercise judgement and draw on experience in evaluating the likely effect of such changes.

Appendix E. Example Building Inspection Form

BUILDINGS EVALUATION FORM #2
U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VII - TOXICS AND PESTICIDES SECTION
324 EAST 11TH STREET
KANSAS CITY, MISSOURI 64106

Date:________

Dist. No.:________

Room:________________________________ Sample Number(s):______________________

Building:________________________ Address:______________________________

Evaluator:______________________________ Phone No.:__________________________

Coated Area: Ceiling Wall(s) Structural Members Above Suspended Ceiling

Pipe Lagging Boiler Insul. Other:______________________

Type of Ceiling: Concrete 3 Coat Plaster System Suspended Metal Lath

Concrete Joists and Beams Tile Suspended Lay-In Panels

Metal Deck Corrugated Steel Steel Beam or Bar Joists

Ceiling Height:___________________ft.

Ceiling Shape: Flat Dome Other (draw):

Folded Plate Barrel

Type of Wall (If Coated): Smooth Concrete Rough Concrete Masonry

Plasterboard Other:___________________________

Amount of Friable Material in Area being Evaluated:____________________sq. ft.

Description of Coating: Fibrous (highly friable) Granular/Cementitious (soft) Concrete Like (hard)

Thickness:__________inch(s) Is thickness uniform: Yes No

Coating debris on Floor/Furniture/Work Surfaces: Yes No

Curtains, expandable partitions, etc. being pulled across coating: Yes No

Type of Lighting: Surface Mounted Suspended Recessed

No. of Lights:_____________ Type of Heating/Cooling Systems:_________________

Type of Floor: Concrete Tile Wood Carpet Other:_______________

What is above the room being evaluated?_______________________________________

____

Comments:____

____

____

E.1 Notes to Appendix E

The need for collecting most of the information on this form is discussed in Chapter 3 (Section 3.3.1). The form requires one additional piece of information: the presence of curtains or expandable partitions which are pulled across asbestos-containing material. Where this situation is found, the curtains or partitions should be removed or repositioned to eliminate contact with the material. Any damage to the asbestos-containing material then can be repaired.

This form was provided by Wolfgang Brandner, the Regional Asbestos Coordinator in Region VII.

Appendix F. Recommended Specifications and Operating Procedures for the Use of Negative Pressure Systems for Asbestos Abatement*

F.1. Introduction

This appendix provides guidelines for the use of negative pressure systems in removing asbestos-containing materials from buildings. A negative pressure system is one in which static pressure in an enclosed work area is lower than that of the environment outside the containment barriers.

The pressure gradient is maintained by moving air from the work area to the environment outside the area via powered exhaust equipment at a rate that will support the desired air flow and pressure differential. Thus, the air moves into the work area through designated access spaces and any other barrier openings. Exhaust air is filtered by a high-efficiency particulate air (HEPA) filter to remove asbestos fibers.

The use of negative pressure during asbestos removal protects against large-scale release of fibers to the surrounding area in case of a breach in the containment barrier. A negative pressure system also can reduce the concentration of airborne asbestos in the work area by increasing the dilution ventilation rate (i.e., diluting contaminated air in the work area with uncontaminated air from outside) and exhausting contaminated air through HEPA filters. The circulation of fresh air through the work area reportedly also improves worker comfort, which may aid the removal process by increasing job productivity.

F.2 Materials and Equipment

F.2.1 The Portable, HEPA-Filtered, Powered Exhaust Unit

The exhaust unit establishes lower pressure inside than outside the enclosed work area during asbestos abatement. Basically, a unit (see Figure F-1) consists of a cabinet with an opening at each end, one for air intake and one for exhaust. A fan and a series of filters are arranged inside the cabinet between the openings. The fan draws contaminated air through the intake and filters and discharges clean air through the exhaust.

Portable exhaust units used for negative pressure systems in asbestos abatement projects should meet the following specifications.

F.2.1.1 Structural Specifications

The cabinet should be ruggedly constructed and made of durable materials to withstand damage from rough handling and transportation. The width of the cabinet should be less than 30 inches to fit through standard-size doorways. The cabinet must be appropriately sealed to prevent asbestos-containing dust from being emitted during use, transport, or maintenance. There should be easy access to all air filters from the intake end, and the filters must be easy

*Information in this Appendix is taken, with modification, from PEDCo Environmental, Inc., April 1982. *Continued Evaluation of Asbestos Removal Technologies and Recommended Specifications of Negative Pressure Systems.* Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3173.

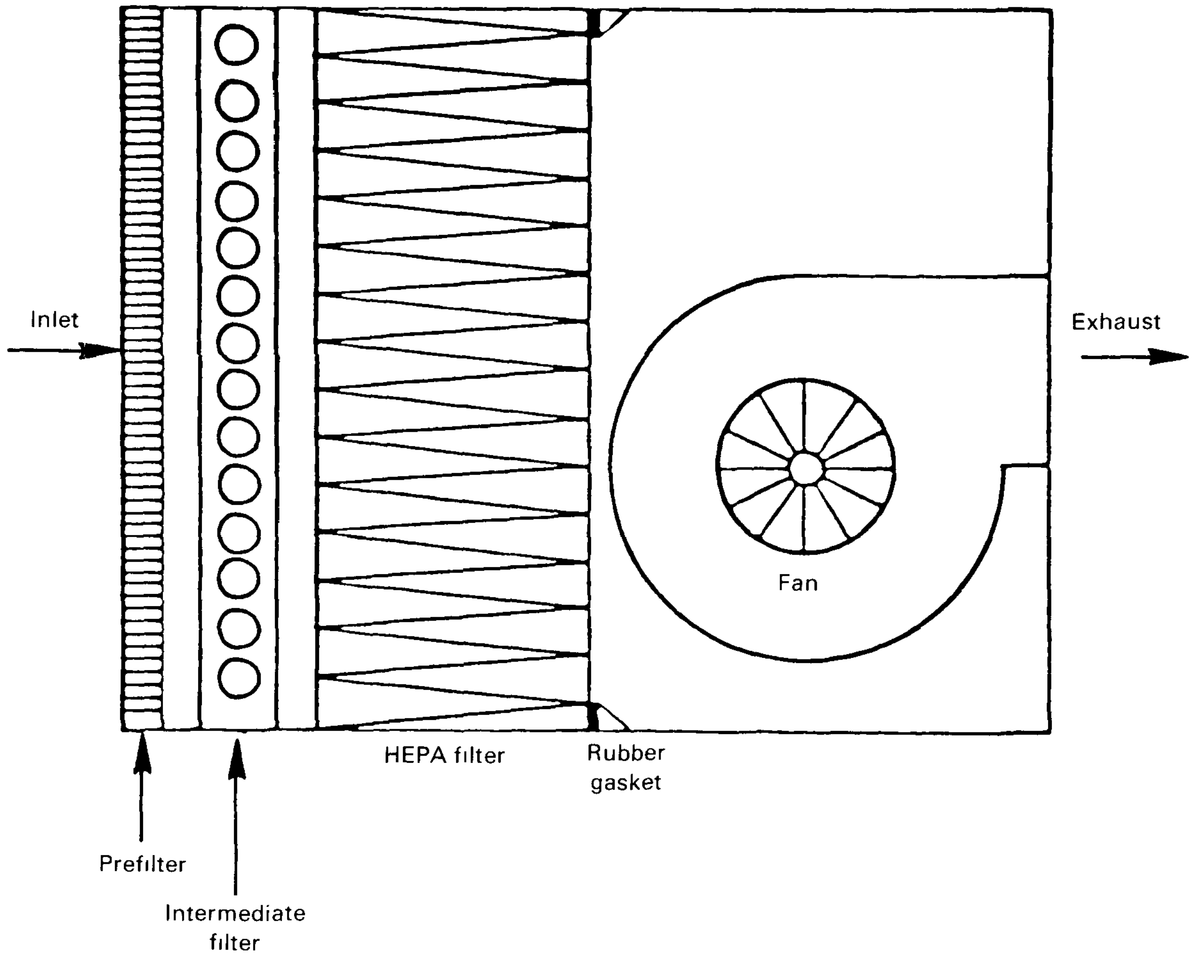


Figure F-1 Sketch of HEPA-filtered exhaust unit

to replace. The unit should be mounted on casters or wheels so it can be easily moved. It also should be accessible for easy cleaning.

F.2.1.2 Mechanical Specifications

F.2.1.2.1 Fans

The fan for each unit should be sized to draw a desired air flow through the filters in the unit at a specified static pressure drop. The unit should have an air-handling capacity of 1,000 to 2,000 ft^3/min (under "clean" filter conditions). The fan should be of the centrifugal type.

For large-scale abatement projects, where the use of a larger capacity, specially designed exhaust system may be more practical than several smaller units, the fan should be appropriately sized according to the proper load capacity established for the application, i.e.,

$$\text{Total ft}^3\text{/min (load)} = \frac{\text{Volume of air in ft}^3 \times \text{air changes/hour}}{\text{60 min/hour}}$$

Smaller-capacity units (e.g., 1,000 ft^3/min) equipped with appropriately sized fans and filters may be used to ventilate smaller work areas. The desired air flow could be achieved with several units.

F.2.1.2.2 Filters

The final filter must be the HEPA type. Each filter should have a standard nominal rating of at least 1,100 ft^3/min with a maximum pressure drop of 1 inch H_2O clean resistance. The filter media (folded into closely pleated panels) must be completely sealed on all edges with a structurally rigid frame and cross-braced as required. The exact dimensions of the filter should correspond with the dimensions of the filter housing inside the cabinet or the dimensions of the filter-holding frame. The recommended standard size HEPA filter is 24 inches high x 24 inches wide x 11-1/2 inches deep. The overall dimensions and squareness should be within 1/8 inch.

A continuous rubber gasket must be located between the filter and the filter housing to form a tight seal. The gasket material should be 1/4 inch thick and 3/4 inch wide.

Each filter should be individually tested and certified by the manufacturer to have an efficiency of not less than 99.97 percent when challenged with 0.3-μm dioctylphthalate (DOP) particles. Testing should be in accordance with Military Standard Number 282 and Army Instruction Manual 136-300-175A. Each filter should bear a UL586 label to indicate ability to perform under specified conditions.

Each filter should be marked with: the name of the manufacturer, serial number, air flow rating, efficiency and resistance, and the direction of test air flow.

Prefilters, which protect the final filter by removing the larger particles, are recommended to prolong the operating life of the HEPA filter. Prefilters prevent the premature loading of the HEPA filter. They can also save energy and cost. One (minimum) or two (preferred) stages of prefiltration may be used. The first-stage prefilter should be a low-efficiency type (e.g., for particles 10 μm and larger). The second-stage (or intermediate) filter should have a medium efficiency (e.g., effective for particles down to 5 μm). Various types of filters and filter media for prefiltration applications are available from many manufacturers. Prefilters and intermediate filters should be installed either on or in the intake grid of the unit and held in place with special housings or clamps.

F.2.1.2.3 Instrumentation

Each unit should be equipped with a Magnehelic gauge or manometer to measure the pressure drop across the filters and indicate when filters have become loaded and need to be changed. The static pressure across the filters (resistance) increases as they become loaded with dust, affecting the ability of the unit to move air at its rated capacity.

F.2.1.3 Electrical

F.2.1.3.1 General

The electrical system should have a remote fuse disconnect. The fan motor should be totally enclosed, fan-cooled, and the nonoverloading type. The unit must use a standard 115-V, single-phase, 60-cycle service. All electrical components must be approved by the National Electrical Manufacturers Association (NEMA) and Underwriter's Laboratories (UL).

F.2.1.3.2 Fans

The motor, fan, fan housing, and cabinet should be grounded. The unit should have an electrical (or mechanical) lockout to prevent the fan from operating without a HEPA filter.

F.2.1.3.3 Instrumentation

An automatic shutdown system that would stop the fan in the event of a major rupture in the HEPA filter or blocked air discharge is recommended. Optional warning lights are recommended to indicate normal operation, too high of a pressure drop across the filters (i.e., filter overloading), and too low of a pressure drop (i.e., major rupture in HEPA filter or obstructed discharge). Other optional instruments include a timer and automatic shut-off and an elapsed time meter to show the total accumulated hours of operation.

F.3 Setup and Use of a Negative Pressure System

F.3.1 Preparation of the Work Area

F.3.1.1 Determining the Ventilation Requirements for a Work Area

Experience with negative pressure systems on asbestos abatement projects indicates a recommended rate of one air change every 15 minutes. The volume (in ft^3) of the work area is determined by multiplying the floor area by the ceiling height. The total air flow requirement (in ft^3/min) for the work area is determined by dividing this volume by the recommended air change rate (i.e., one air change every 15 minutes).*

$$\text{Total } ft^3/min = \text{Volume of work area (in } ft^3)/15 \text{ min}$$

The number of units needed for the application is determined by dividing the total ft^3/min by the rated capacity of the exhaust unit.

$$\text{Number of units needed} = [\text{Total } ft^3/min]/[\text{Capacity of unit (in } ft^3)]$$

F.3.1.2 Location of Exhaust Units

The exhaust unit(s) should be located so that makeup air enters the work area primarily through the decontamination facility and traverses the work area as much as possible. This may be accomplished by positioning the exhaust unit(s) at a maximum distance from the worker access opening or other makeup air sources.

Wherever practical, work area exhaust units can be located on the floor in or near unused doorways or windows. The end of the unit or its exhaust duct should be placed through an opening in the plastic barrier or wall covering. The plastic around the unit or duct should then be sealed with tape.

---

*The recommended air exchange rate is based on engineering judgment.

Each unit must have temporary electrical power (115V AC). If necessary, three-wire extension cords can supply power to a unit. The cords must be in continuous lengths (without splice), in good condition, and should not be more than 100 feet long. They must not be fastened with staples, hung from nails, or suspended by wire. Extension cords should be suspended off the floor and out of workers' way to protect the cords from damage from traffic, sharp objects, and pinching.

Wherever possible, exhaust units should be vented to the outside of the building. This may involve the use of additional lengths of flexible or rigid duct connected to the air outlet and routed to the nearest outside opening. Windowpanes may have to be removed temporarily.

If exhaust air cannot be vented to the outside of the building or if cold temperatures necessitate measures to conserve heat and minimize cold air infiltration, filtered air that has been exhausted through the barrier may be recirculated into an adjacent area. However, this is not recommended.

Additional makeup air may be necessary to avoid creating too high of a pressure differential, which could cause the plastic coverings and temporary barriers to "blow in." Additional makeup air also may be needed to move air most effectively through the work area. Supplemental makeup air inlets may be made by making openings in the plastic sheeting that allow air from outside the building into the work area. Auxiliary makeup air inlets should be as far as possible from the exhaust unit(s) (e.g., on an opposite wall), off the floor (preferably near the ceiling), and away from barriers that separate the work area from occupied clean areas. They should be resealed whenever the negative pressure system is turned off after removal has started. Because the pressure differential (and ultimately the effectiveness of the system) is affected by the adequacy of makeup air, the number of auxiliary air inlets should be kept to a minimum to maintain negative pressure. Figure F-2 presents examples of negative pressure systems denoting the location of HEPA-filtered exhaust units and the direction of air flow.

F.3.2 Use of the Negative Pressure System

F.3.2.1 Testing the System

The negative pressure system should be tested before any asbestos-containing material is wetted or removed. After the work area has been prepared, the decontamination facility set up, and the exhaust unit(s) installed, the unit(s) should be started (one at a time). Observe the barriers and plastic sheeting. The plastic curtains of the decontamination facility should move slightly in toward the work area. The use of ventilation smoke tubes and a rubber bulb is another easy and inexpensive way to visually check system performance and direction of air flow through openings in the barrier. Another test is to use a Magnehelic gauge (or other instrument) to measure the static pressure differential across the barrier. The measuring device must be sensitive enough to detect a relatively low pressure drop. A Magnehelic gauge with a scale of 0 to 0.25 or 0.50 inch of H_2O and 0.005 or 0.01 inch graduations is generally adequate. The pressure drop across the barrier is measured from the outside by punching a small hole in the plastic barrier and inserting one end of a piece of rubber or Tygon tubing. The other end of the tubing is connected to the "low pressure" tap of the instrument. The "high pressure" tap must be open to the atmosphere. The pressure is read directly from the scale. After the test is completed, the hole in the barrier must be patched.

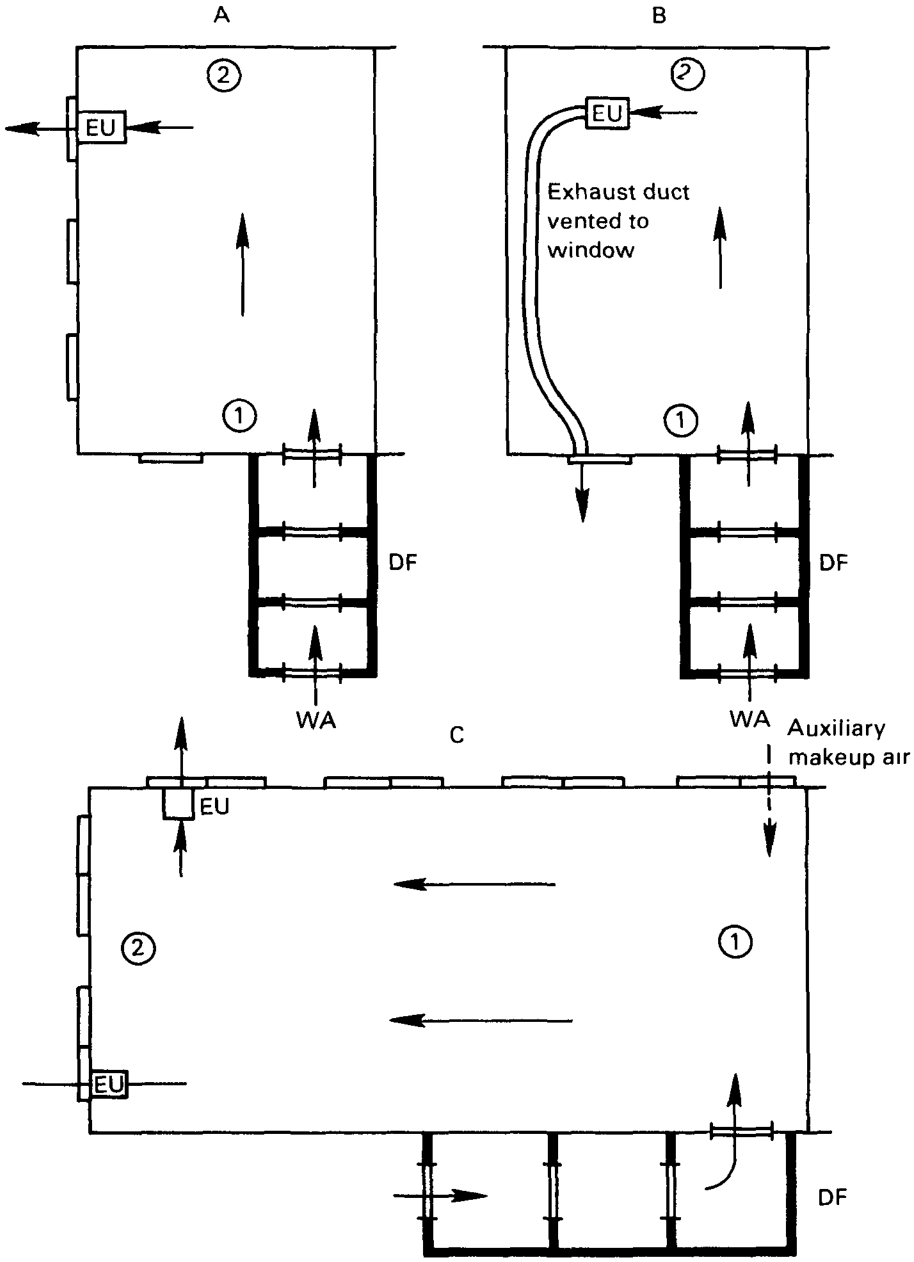


Figure F-2. Examples of negative pressure systems. DF, Decontamination Facility; EU, Exhaust Unit; WA, Worker Access; A, Single-room work area with multiple windows; B, Single-room work area with single window near entrance; C, Large single-room work area with windows and auxiliary makeup air source (dotted arrow). Arrows denote direction of air flow. Circled numbers indicate progression of removal sequence.

F.3.2.2 Use of System During Removal Operations

The exhaust units should be started just before beginning removal (i.e., before any asbestos-containing material is disturbed). After removal has begun, the units should run continuously to maintain a constant negative pressure until decontamination of the work area is complete. The units should not be turned off at the end of the work shift or when removal operations temporarily stop.

Employees should start removing the asbestos material at a location farthest from the exhaust units and work toward them. If an electric power failure occurs, removal must stop immediately and should not resume until power is restored and exhaust units are operating again.

Because airborne asbestos fibers are microscopic in size and tend to remain in suspension for a long time, the exhaust units must keep operating throughout the entire removal and decontamination processes. To ensure continuous operation, a spare unit should be available.

After asbestos removal equipment has been moved from the work area, the plastic sheeting has been cleaned, and all surfaces in the work area have been wet-cleaned, the exhaust units can be allowed to run for at least another 4 hours to remove airborne fibers that may have been generated during wet removal and cleanup and to purge the work area with clean makeup air. The units may be allowed to run for a longer time after decontamination, particularly if dry or only partially wetted asbestos material was encountered during removal.

F.3.2.2.1 Filter Replacement

All filters must be accessible from the work area or "contaminated" side of the barrier. Thus, personnel responsible for changing filters while the negative pressure system is in use should wear approved respirators and other protective equipment. The operating life of a HEPA filter depends on the level of particulate contamination in the environment in which it is used. During use, filters will become loaded with dust, which increases resistance to air flow and diminishes the air-handling capacity of the unit. The difference in pressure drop across the filters between "clean" and "loaded" conditions (ΔP) is a convenient means of estimating the extent of air-flow resistance and determining when the filters should be replaced.

When ΔP across the filters (as determined by the Magnehelic gauge or manometer on the unit) exceeds 1.0 inch of H_2O, the prefilter should be replaced first. The prefilter, which fan suction will generally hold in place on the intake grill, should be removed with the unit running by carefully rolling or folding in its sides. Any dust dislodged from the prefilter during removal will be collected on the intermediate filter. The used prefilter should be placed inside a plastic bag, sealed and labeled, and disposed of as asbestos waste. A new prefilter is then placed on the intake grill. Filters for prefiltration applications may be purchased as individual precut panels or in a roll of specified width that must be cut to size.

If the ΔP still exceeds 1.0 inch of H_2O after the prefilter has been replaced, the intermediate filter is replaced. With the unit operating, the prefilter should be removed, the intake grill or filter access opened, and the intermediate filter removed. Any dust dislodged from the intermediate filter during removal will be collected on the HEPA filter. The used intermediate filter should be placed in a sealable plastic bag (appropriately labeled) and disposed of as asbestos waste. A new replacement filter is then installed and the grill or access closed. Finally, the prefilter on the intake grill should be replaced.

The HEPA filter should be replaced if prefilter and/or intermediate filter replacement does not restore the pressure drop across the filters to its original clean resistance reading or if the HEPA filter becomes damaged. The exhaust unit is shut off to replace the HEPA filter, which requires removing the prefilter first, then opening the intake grill or filter access, and finally removing the HEPA filter from the unit. Used HEPA filters should be placed in a sealable plastic bag (appropriately labeled) and disposed of as asbestos waste. A new HEPA filter (structurally identical to the original filter) should then be installed. The intake grill and intermediate filter should be put back in place, the unit turned on, and the prefilter positioned on the intake grill. Whenever the HEPA filter is replaced, the prefilter and intermediate filter should also be replaced.

When several exhaust units are used to ventilate a work area, any air movement through an inactive unit during the HEPA filter replacement will be into the work area. Thus, the risk of asbestos fiber release to the outside environment is controlled.

Any filters used in the system may be replaced more frequently than the pressure drop across the filters indicates is necessary. Prefilters, for example, may be replaced two to four times a day or when accumulations of particulate matter become visible. Intermediate filters must be replaced once every day or so, and the HEPA filter may be replaced at the beginning of each new project. (Used HEPA filters must be disposed of as asbestos-containing waste.) Conditions in the work area dictate the frequency of filter changes. In a work area where fiber release is effectively controlled by thorough wetting and good work practices, fewer filter changes may be required than in work areas where the removal process is not well controlled. It should also be noted that the collection efficiency of a filter generally improves as particulate accumulates on it. Thus, filters can be used effectively until resistance (as a result of excessive particulate loading) diminishes the exhaust capacity of the unit.

F.3.2.3 Dismantling the System

When a final inspection and the results of final air tests indicate that the area has been decontaminated, all filters of the exhaust units should be removed and disposed of properly and the units shut off. The remaining barriers between contaminated and clean areas and all seals on openings into the work area and fixtures may be removed and disposed of as contaminated waste. A final check should be made to be sure that no dust or debris remain on surfaces as a result of dismantling operations.

Appendix G. Estimation of Fiber Detection Limit Using the NIOSH Membrane Filter Method (P&CAM 239)

The NIOSH Membrane Filter Method for measuring airborne fibers is used to determine compliance with the OSHA exposure standard for asbestos. The lowest level at which fibers can be reliably detected (detection limit) is reported to be 0.1 fibers per cubic centimeter.* However, the detection limit depends on total volume of air sampled and decreases as the volume increases. For uses of this method other than determining compliance with OSHA, a detection limit should be calculated in conjunction with specifying a sampling time and a sampling rate.

Based on a study of counting fibers with phase contrast microscopy, NIOSH has specified that at least 10 fibers must be observed in 100 microscopic fields.† The lower detection limit (expressed in fibers per cubic centimeter) can be calculated from this value as follows:

$$DL = [(10 \text{ fibers}/100 \text{ fields})/V]\,(FA/MFA)\,(1 \text{ liter}/1{,}000 \text{ cm}^3)$$

where:

DL = detection limit in fibers/cubic centimeter

V = volume of air sampled in liters

FA = effective collecting area of the filter in square millimeters (typically 855 mm^2)

MFA = microscopic field area in square millimeters (typically 0.003-0.006 mm^2)

For a sampling time of 8 hours at a rate of 2 liters per minute, the V is 960 liters and, assuming FA is 855 and MFA is 0.003 square millimeters, the DL is approximately 0.03 fibers per cubic centimeter:

$$V = (2 \text{ liters/min})\,(60 \text{ min/hour})\,(8 \text{ hours}) = 960 \text{ liters}$$

$$DL = \left(\frac{10 \text{ fibers}/100 \text{ fields}}{960 \text{ liters/filter}}\right)\left(\frac{855 \text{ mm}^2/\text{filter}}{0.003 \text{ mm}^2/\text{field}}\right)\left(\frac{1 \text{ liter}}{1{,}000 \text{ cm}^3}\right)$$

$$DL = 0.0297 \text{ fibers/cm}^3$$

Because of differences between microscopes, the size of field of view may vary. Most microscopes have an MFA at the 100 x magnification between 0.003 and 0.006 mm^2. For an MFA of 0.006 mm^2, the DL in the above example would be 0.0148 fibers/cm^3.

The effective collecting area will also vary with the filter size. The FA is 855 mm^2 for a 37 mm filter.

---

*Leidel NA, Boyer SG, Zumwalde RD, Busch KA. February 1979. *USPHS/NIOSH Membrane Filter Method for Evaluating Airborne Asbestos Fiber.* Washington, DC: National Institute of Occupational Safety and Health.

†The coefficient of variation (standard deviation divided by the mean) is reported to be 41 percent when counting an average of 10 fibers per 100 fields. (Leidel, *op cit.*)

Appendix H. Glossary

Asbestos — A group of naturally occurring minerals that separate into fibers. There are six asbestos minerals used commercially: Chrysotile, Amosite, Crocidolite, Anthophyllite, Tremolite, and Actinolite.

Cementitious — Friable materials that are densely packed and nonfibrous.

Delaminate — To separate into layers. As used here, to separate from the substrate.

(Human) Exposure — The presence of people in an area where levels of an airborne contaminant are elevated. A more technical definition sometimes *found in scientific literature is: The total amount of airborne* contaminant inhaled by a person, typically approximated by the product of concentration and duration.

(Material) Exposure — The amount or fraction of material visible.

Fibrous — Spongy, fluffy, composed of long strands of fibers.

Friable — Capable of being crumbled, pulverized, or reduced to powder by hand pressure.

Homogeneous — Similar in appearance and texture.

Peak levels — Levels of airborne containment which are much higher than average and occur for short periods of time in response to sudden release of the contaminant.

Prevalent levels — Levels of airborne contaminant occurring under normal conditions.

Resolve — To distinguish different objects with a microscope.

Risk — The likelihood of developing a disease as a result of exposure to a contaminant.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 560/5-83-002	2.	3. Recipient's Accession No

4. Title and Subtitle
Guidance for Controlling Friable Asbestos-Containing Materials in Buildings

5. Report Date
March 1983

6.

7. Author(s)
DALE L. KEYES, BERTRAM P. PRICE

8. Performing Organization Rept. No

9. Performing Organization Name and Address
BATTELLE MEMORIAL INSTITUTE
Columbus Division
2030 M Street, N. W.
Washington, D. C. 20036

10. Project/Task/Work Unit No

11. Contract(C) or Grant(G) No
(C) 68-01-5915
68-01-6721
(G)

12. Sponsoring Organization Name and Address
Environmental Protection Agency
Office of Pesticides and Toxic Substances
Washington, D. C. 20460

13. Type of Report & Period Covered

14.

15. Supplementary Notes
This report was prepared for The Exposure Evaluation Division of The Office of Toxic Substances. Questions about information in the document should be directed to Joe Breen or Cindy Stroup (202)382-3569/3891.

16. Abstract (Limit: 200 words)

This document provides information that supplements previous EPA guidance on controlling asbestos-containing materials found in buildings. The document (1) provides a current summary of data on exposure to airborne asbestos, (2) identifies organizational and procedural issues in establishing an asbestos control program, (3) reviews technical issues confronted when assessing the potential for exposure to airborne asbestos in particular indoor settings, (4) summarizes and updates information on applicability, effectiveness, and relative costs of alternative remedial actions, (5) suggests a structured process for selecting a particular course of action given information on exposure levels, assessment methods, and abatement techniques, (6) introduces and discusses criteria for determining successful asbestos control. The material presented is a summary of information and experience gained over the 4 years since previous guidance was published.

17. Document Analysis a. Descriptors
Airborne Asbestos
Asbestos Abatement
Asbestos-Containing Materials
Asbestos Control Program
Asbestos Exposure

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
	20. Security Class (This Page)	22. Price

(See ANSI–Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4–77)
(Formerly NTIS–35)
Department of Commerce

U S GOVERNMENT PRINTING OFFICE 1984 447-487/18814